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Wakabayashi et al.

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(54) **HIGH-FREQUENCY SIGNAL TRANSMISSION LINE AND ELECTRONIC DEVICE**

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H05K 1/02 (2006.01)
(Continued)

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CPC ***H05K 1/0242*** (2013.01); ***H01P 3/081*** (2013.01); ***H01P 3/085*** (2013.01); ***H01P 5/028*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01P 3/08; H01P 3/081; H01P 3/082; H01P 3/085; H01P 3/088; H05K 1/024; H05K 2201/0715
USPC 333/238, 246
See application file for complete search history.

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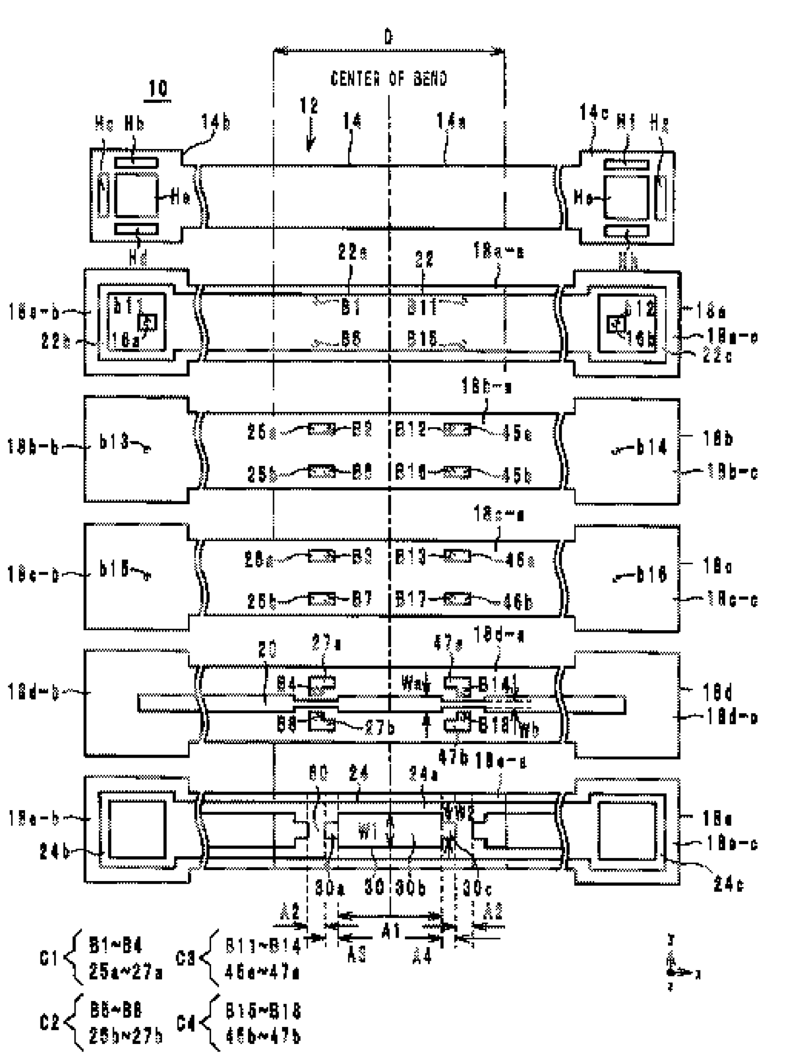
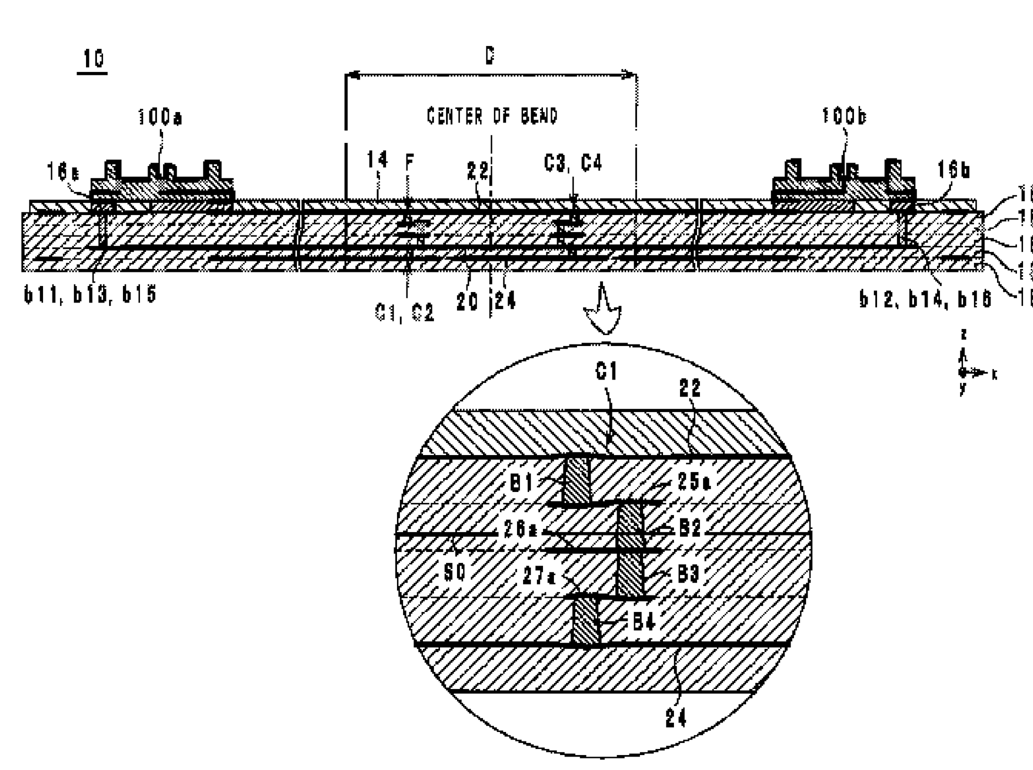
(57) **ABSTRACT**

A high-frequency signal transmission line includes a first ground conductor located at one side in a stacking direction of a stacked body of dielectric layers in relation to a signal line; a second ground conductor located at another side in the stacking direction in relation to the signal line; and a connection portion including interlayer connection conductors and connection conductors to connect the first ground conductor to the second ground conductor. Two of the interlayer connection conductors constituting both ends in the stacking direction of the connection portion are located farther away from a center of a bending section of the body than the other interlayer connection conductors. Openings are provided respectively in ones of the dielectric layers located at the one side and the another side in the stacking direction in relation to the other interlayer connection conductors, at positions that overlap with the other interlayer connection conductors.

18 Claims, 13 Drawing Sheets





(51) **Int. Cl.**

H01P 5/02	(2006.01)
H04B 5/00	(2006.01)
H05K 1/11	(2006.01)
H05K 1/14	(2006.01)

(52) **U.S. Cl.**
CPC ***H04B 5/00*** (2013.01); *H05K 1/025* (2013.01); *H05K 1/028* (2013.01); *H05K 1/0225* (2013.01); *H05K 1/0251* (2013.01); *H05K 1/118* (2013.01); *H05K 1/147* (2013.01); *H05K 2201/10189* (2013.01)

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FIG. 1A

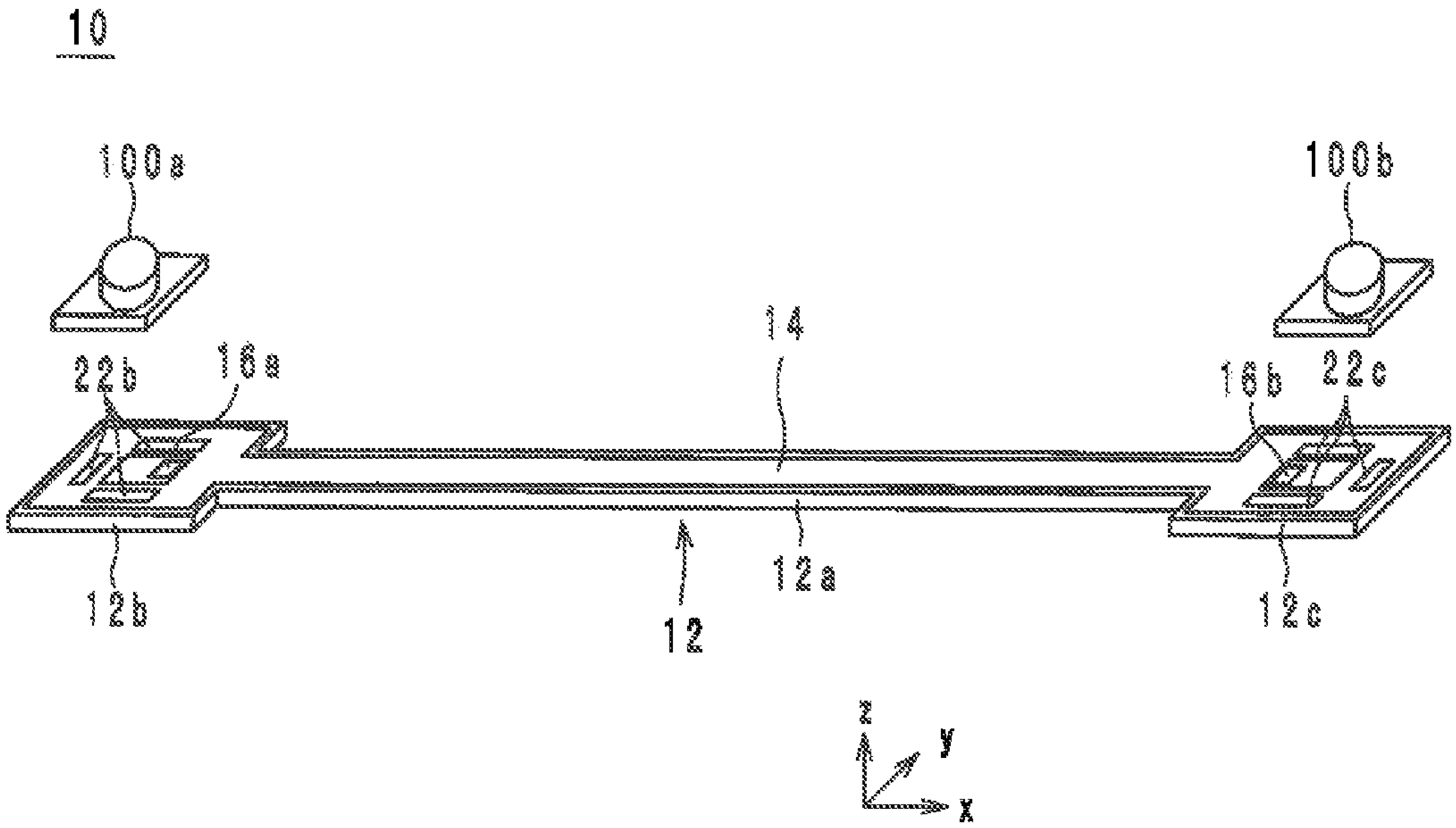

10
100a
100b
14
22b
16a
16b
22c
12b
12a
12c
12
z
y
x

FIG. 1B

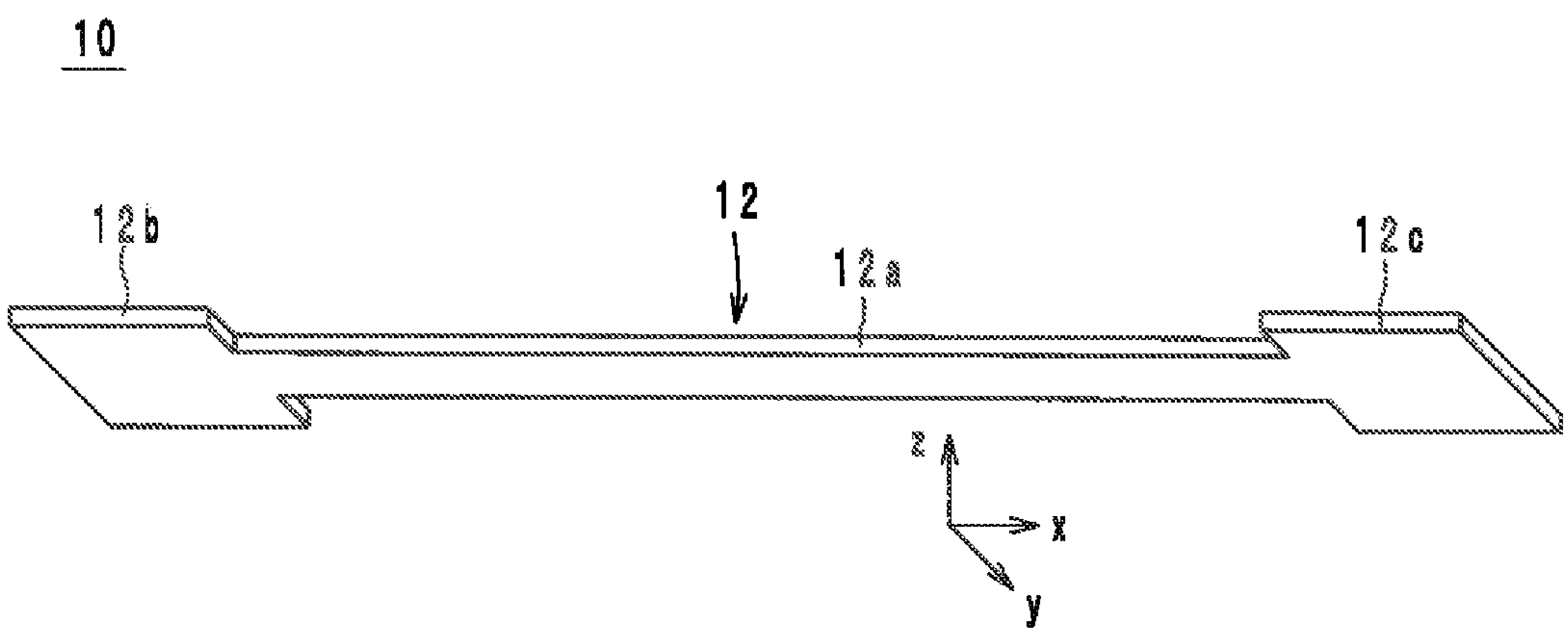

10
12
12b
12a
12c
z
x
y

FIG. 2

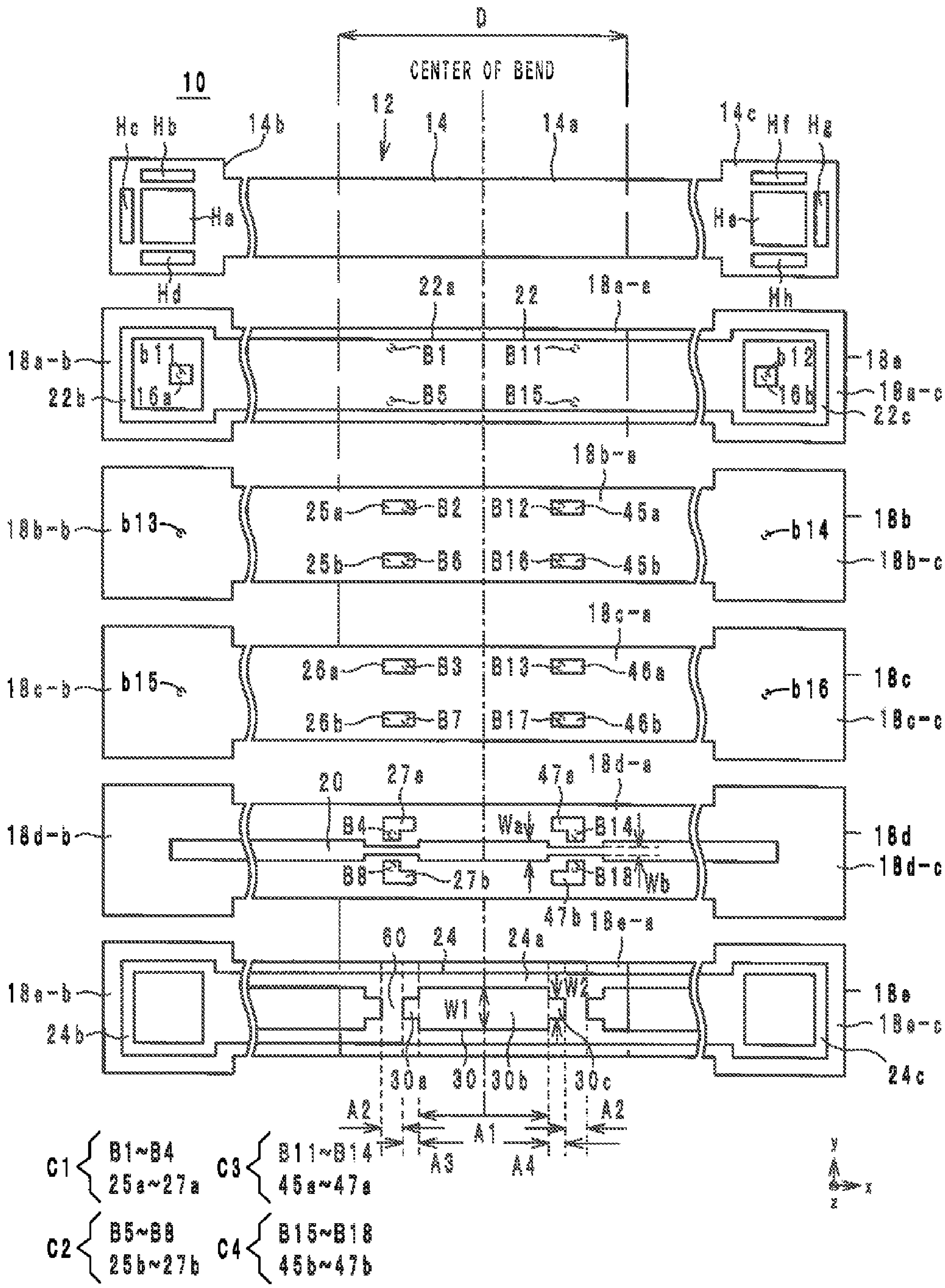

D
CENTER OF BEND
10
12
14
14a
14b
14c
Hc Hb
Hf Hg
Ha
He
Hd
Hh
22a
22
18a-a
18a-b
18a
18a-c
22b
22c
b11
b12
16a
16b
B1
B11
B5
B15
18b-a
18b-b
18b
18b-c
b13
b14
25a
B2
B12
45a
25b
B6
B16
45b
18c-a
18c-b
18c
18c-c
b15
b16
26a
B3
B13
46a
26b
B7
B17
46b
20
27a
47a
18d-a
18d-b
18d
18d-c
B4
Wa
B14
B8
27b
B18
Wb
47b
60
24
24a
18e-a
18e-b
18e
18e-c
24b
24c
W1
W2
30a
30
30b
30c
A2
A1
A2
A3
A4
C1 B1~B4 25a~27a
C3 B11~B14 45a~47a
C2 B5~B8 25b~27b
C4 B15~B18 45b~47b
y
x
z

FIG. 3A

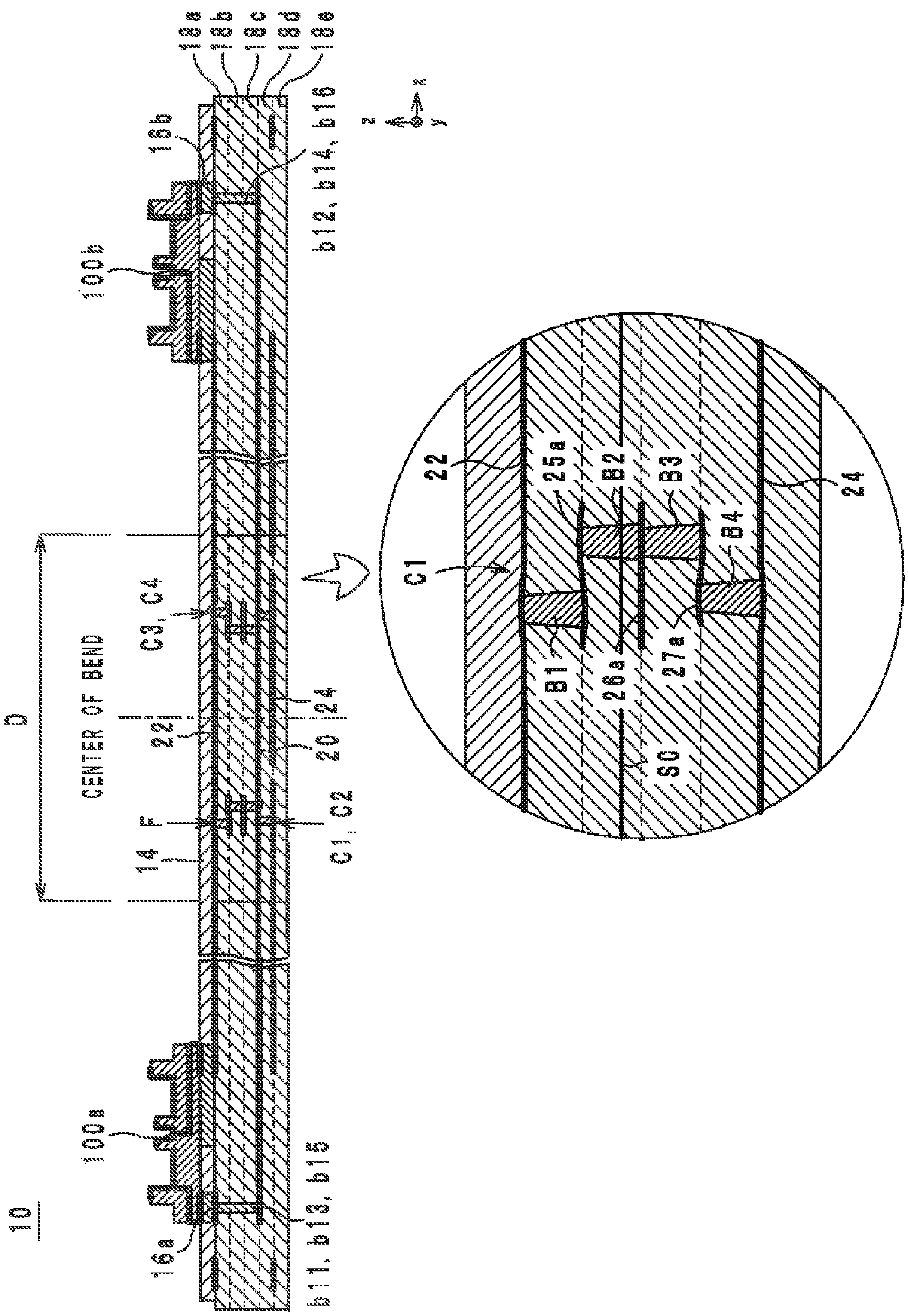

10
18a
18b
18c
18d
18e
16b
100b
b12, b14, b16
D
CENTER OF BEND
C3, C4
22
24
20
14
F
C1, C2
100a
16a
b11, b13, b15
C1
22
25a
B2
B3
24
B4
B1
26a
27a
S0

FIG. 3B

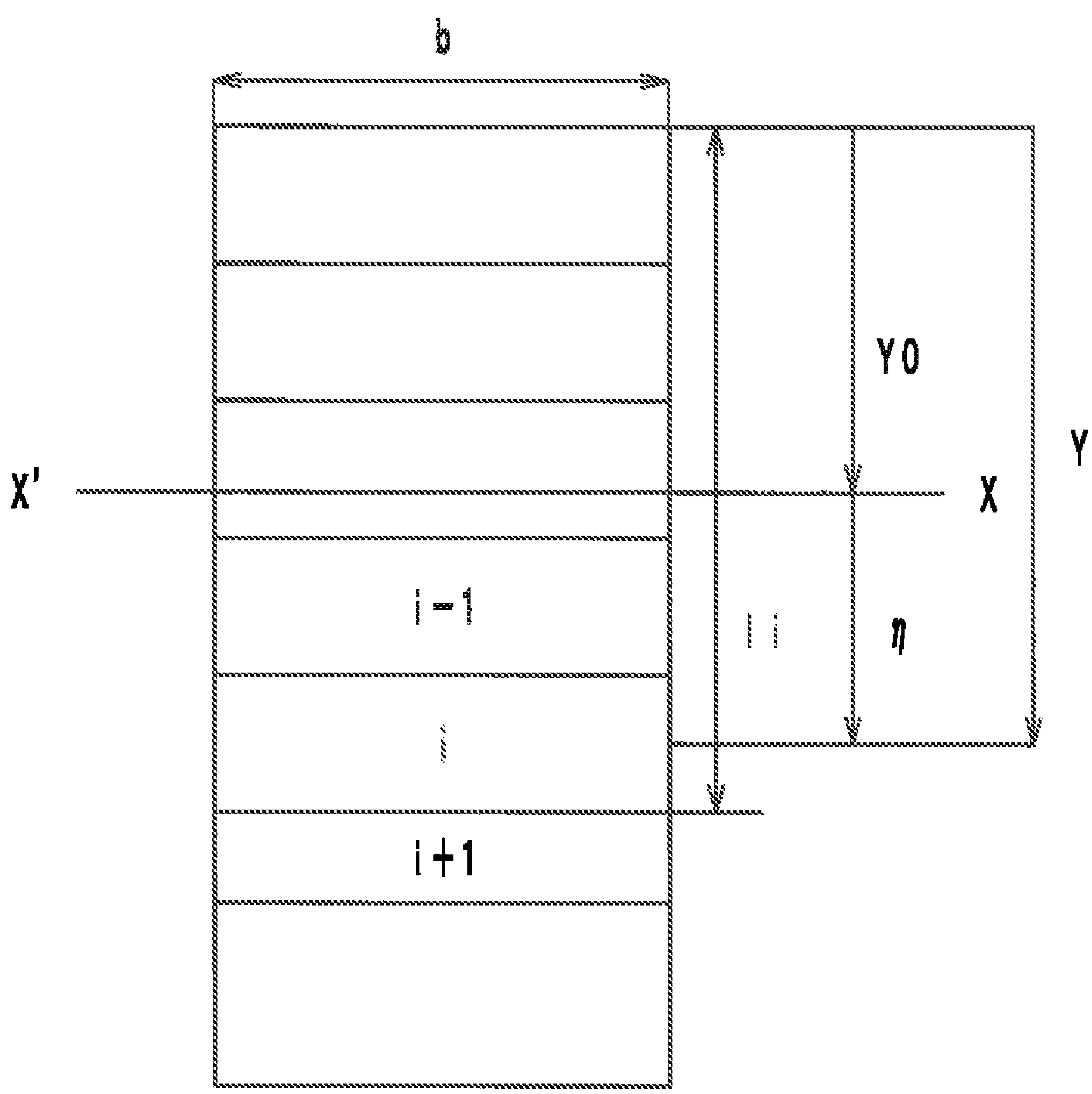


FIG. 4A

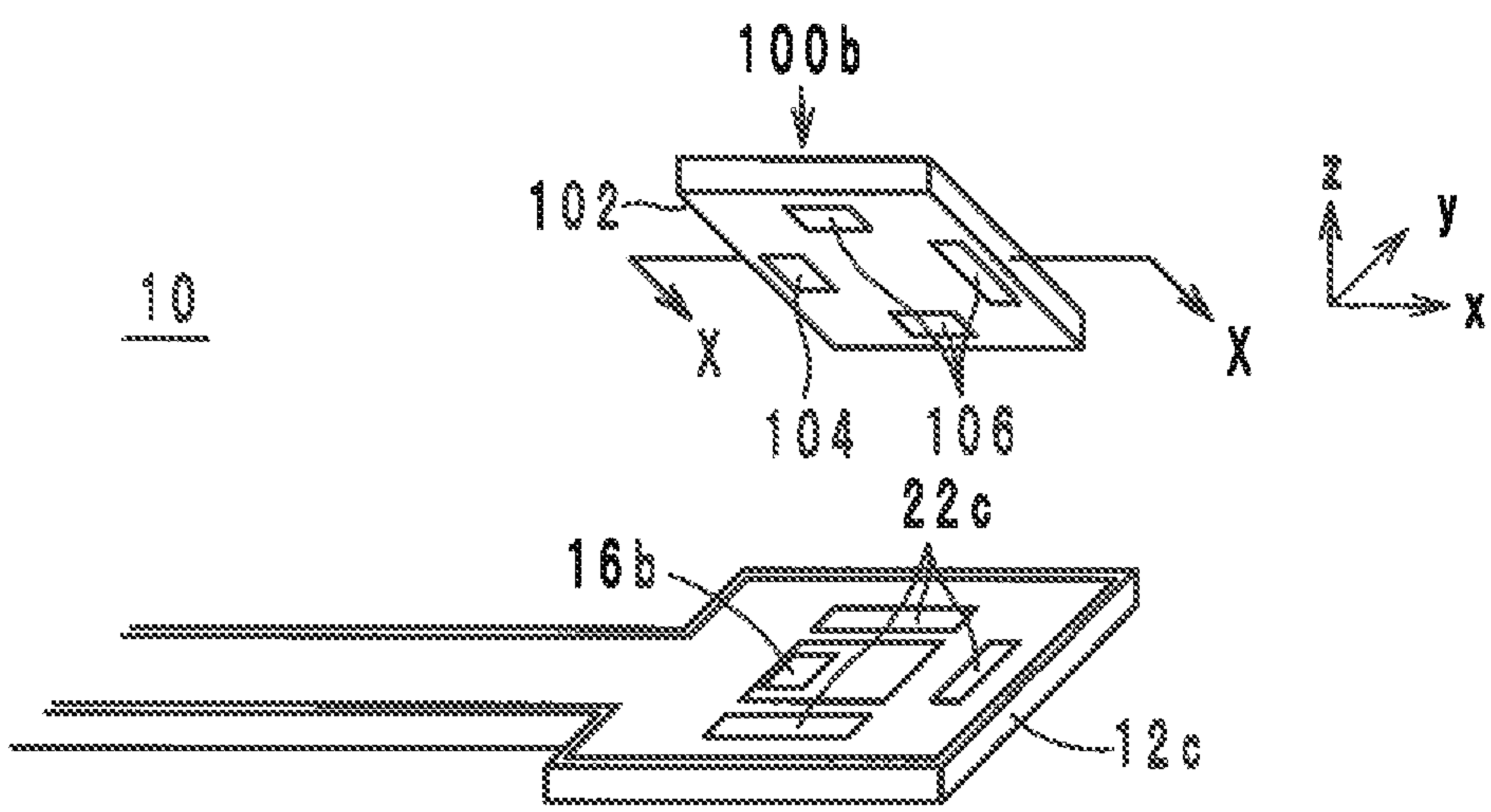

100b
102
10
z
y
x
X
X
104
106
22c
16b
12c

FIG. 4B

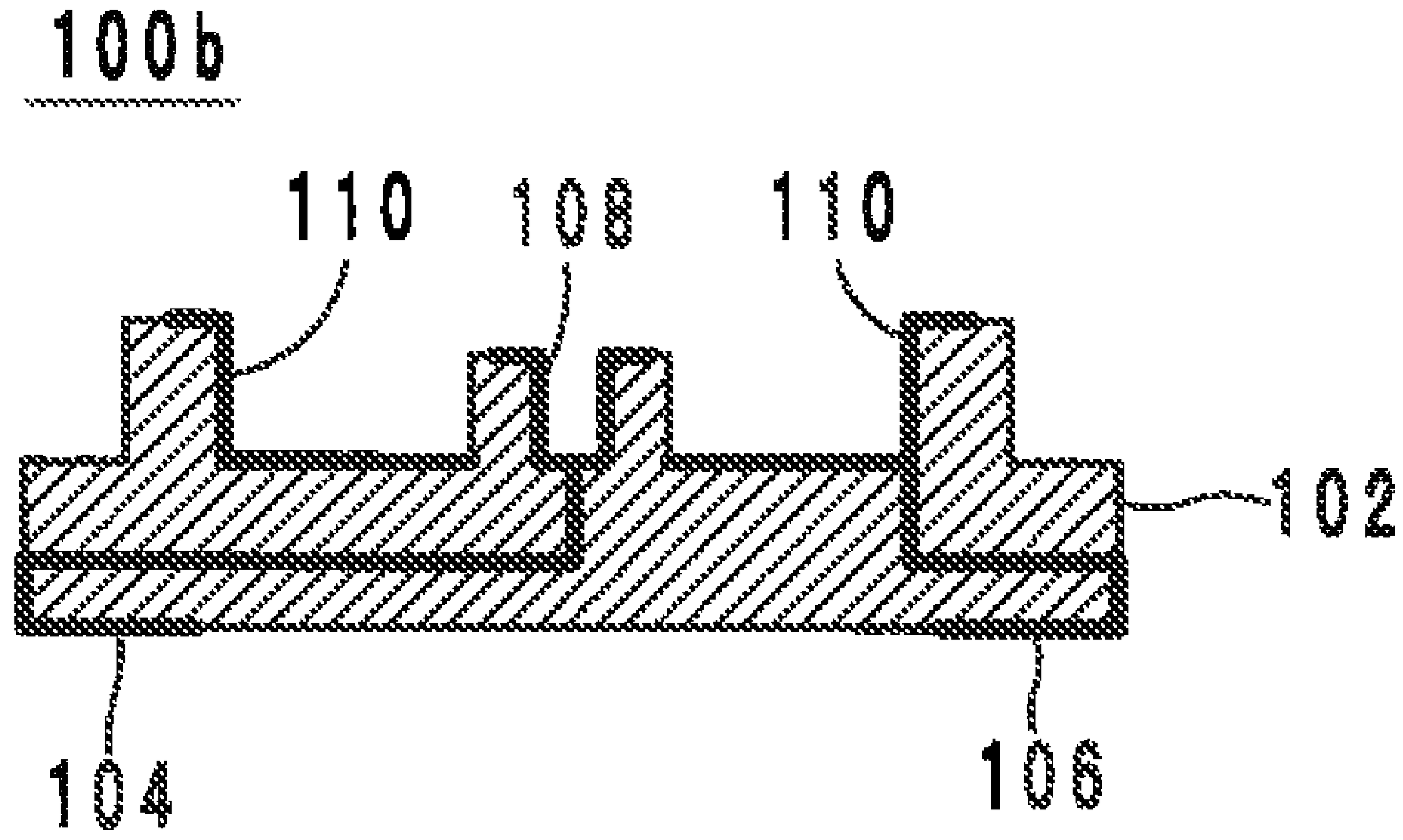

100b
110
108
110
102
104
106

FIG. 5A

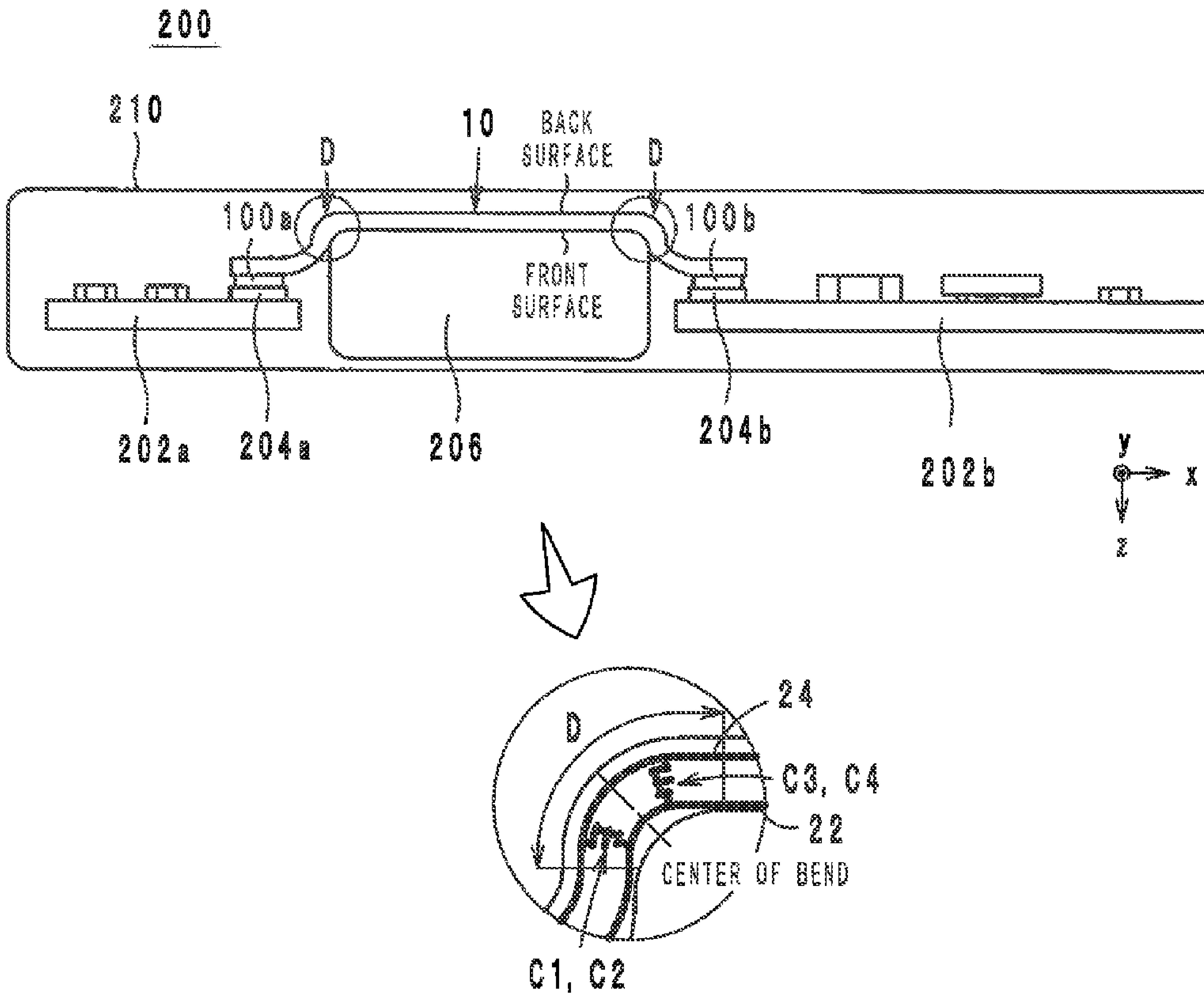

200
210
10
BACK SURFACE
D
D
100a
100b
FRONT SURFACE
202a
204a
206
204b
202b
y
x
z
24
D
C3, C4
22
CENTER OF BEND
C1, C2

FIG. 5B

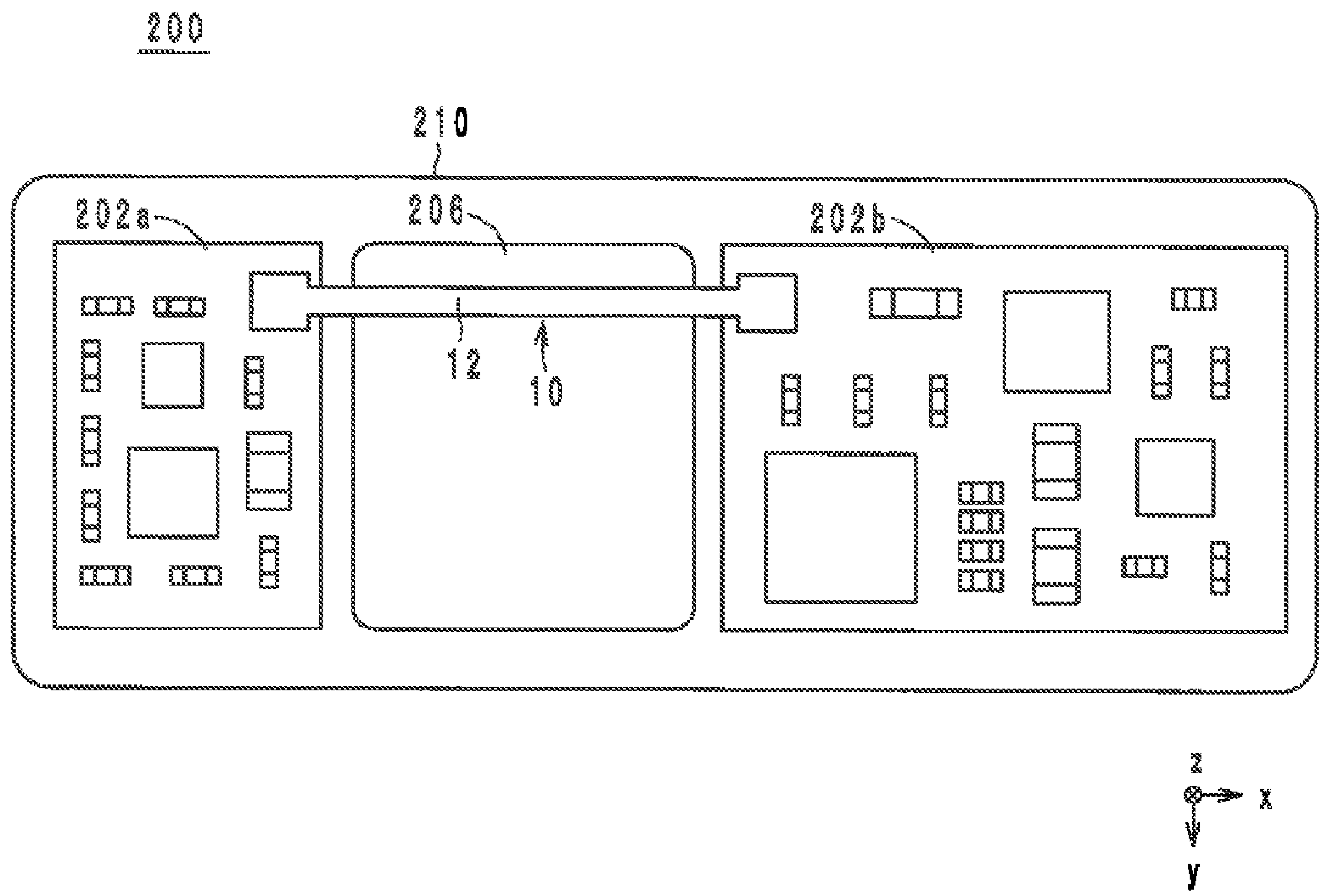


FIG. 5C

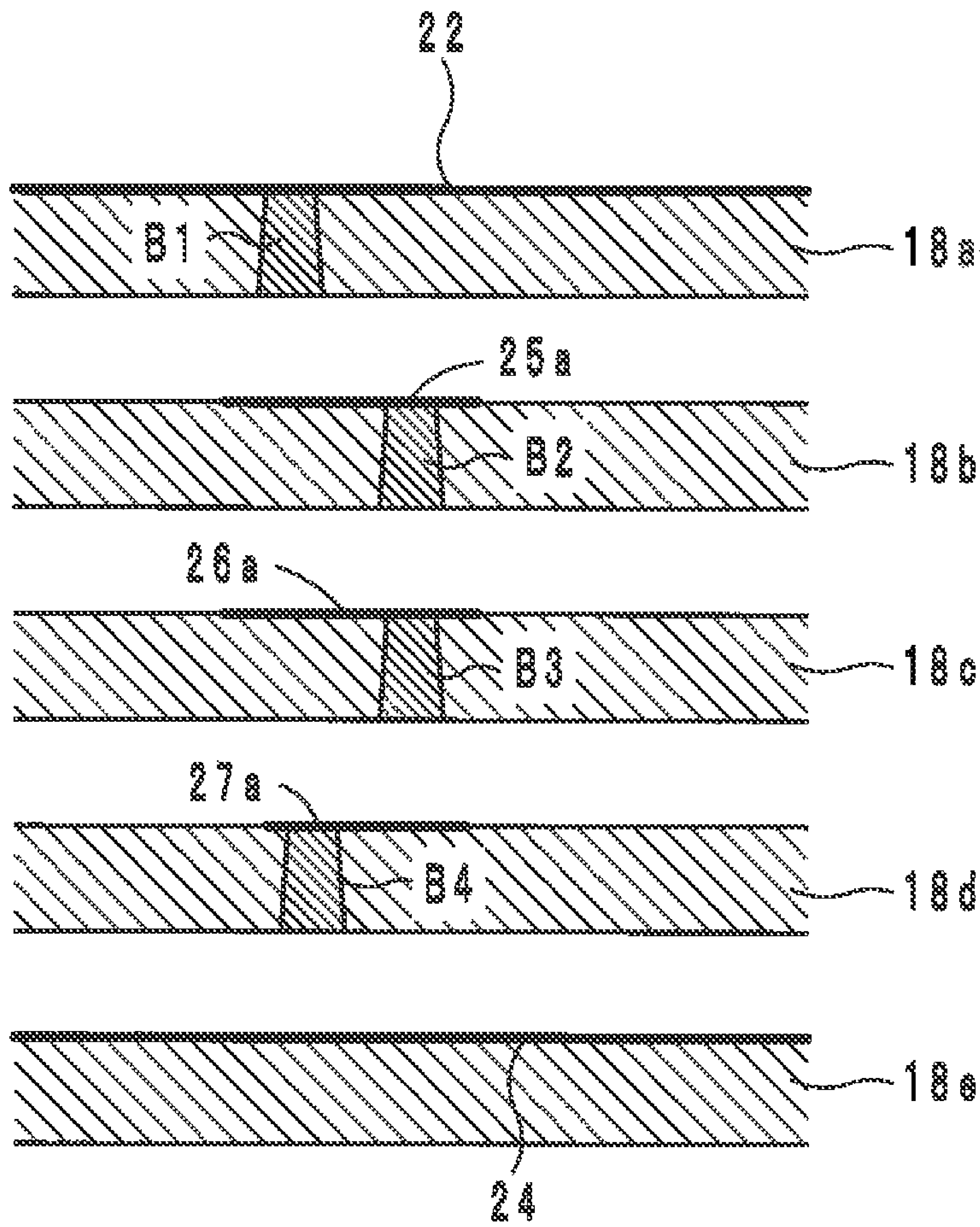


FIG. 6

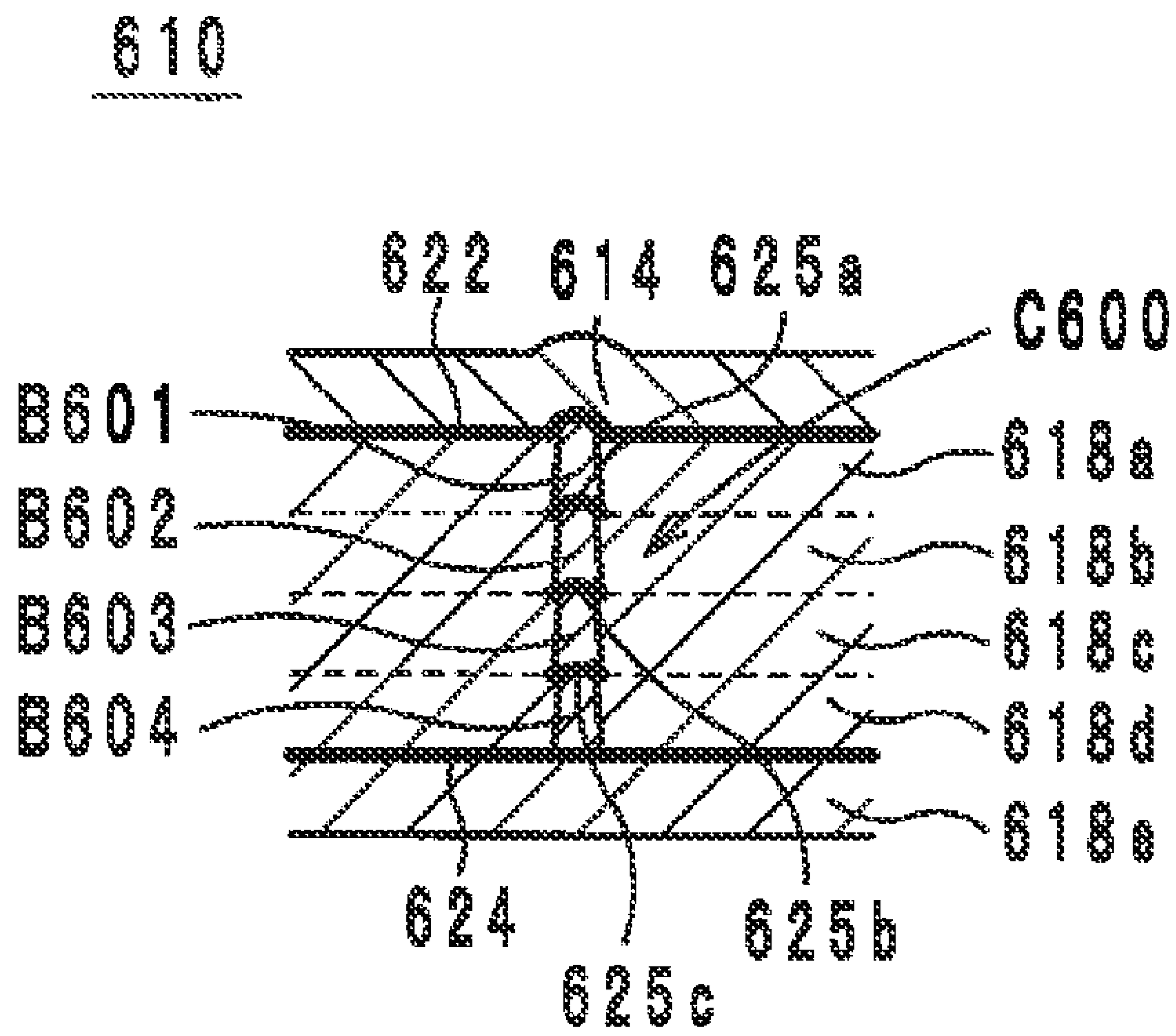

610
622
614
625a
C600
B601
B602
B603
B604
618a
618b
618c
618d
618e
624
625c
625b

FIG. 7

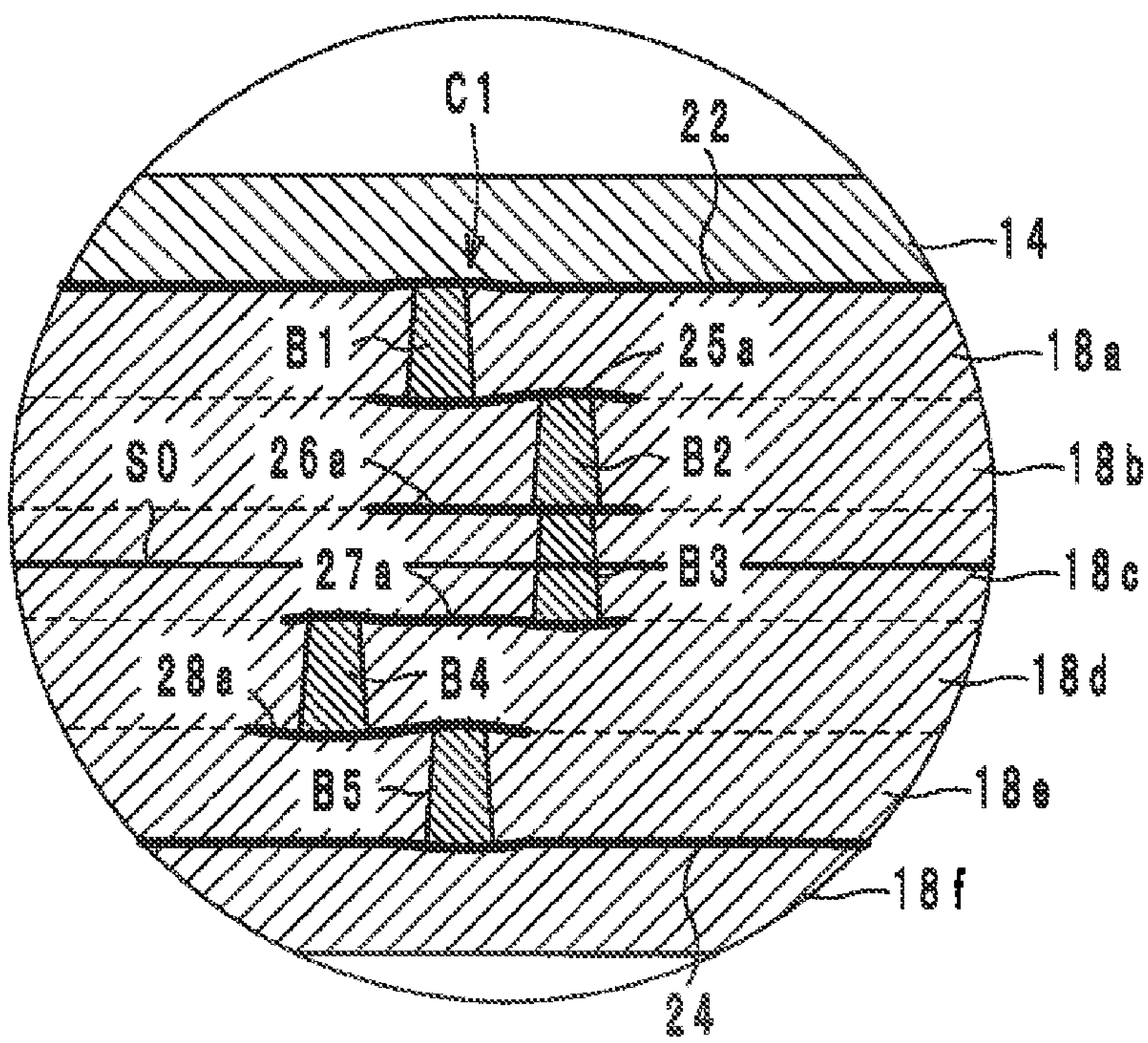

C1
22
14
B1
25a
18a
S0
26a
B2
18b
27a
B3
18c
28a
B4
18d
B5
18e
18f
24

FIG. 8A

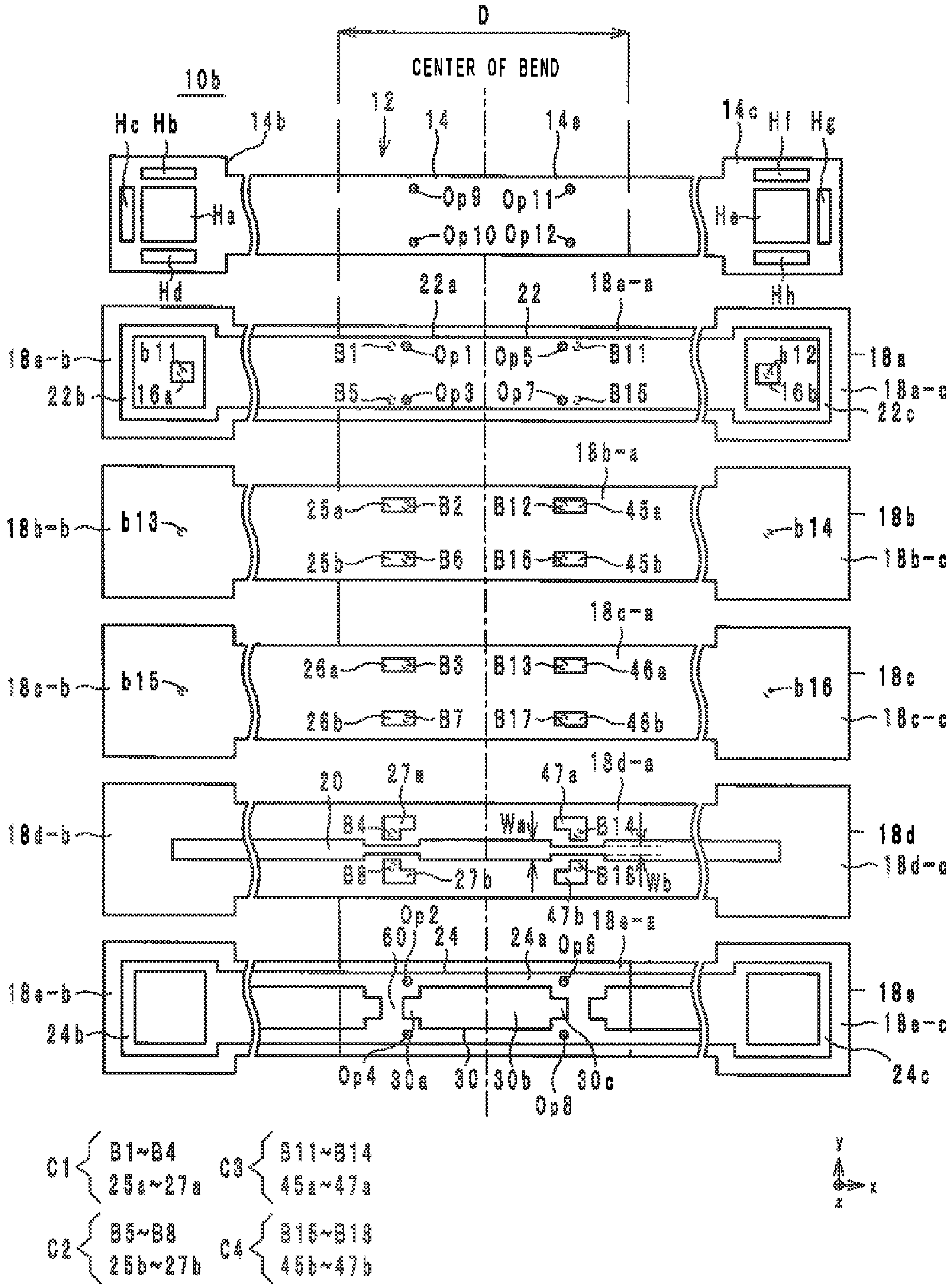

D
CENTER OF BEND
10b
12
14
14a
14b
14c
Hc Hb
Hf Hg
Ha
He
Hd
Hh
Op9
Op11
Op10
Op12
22a
22
18a-a
18a-b
b11
16a
22b
B1
Op1
Op5
B11
B5
Op3
Op7
B15
b12
16b
18a
18a-c
22c
18b-a
18b-b
b13
25a
B2
B12
45a
25b
B6
B16
45b
b14
18b
18b-c
18c-a
18c-b
b15
26a
B3
B13
46a
26b
B7
B17
46b
b16
18c
18c-c
20
27a
47a
18d-a
18d-b
B4
Wa
B14
18d
B8
27b
B18
Wb
18d-c
Op2
47b
18e-a
60
24
24a
Op6
18e-b
24b
18e
18e-c
24c
Op4
30a
30
30b
30c
Op8
C1 B1~B4 25a~27a
C3 B11~B14 45a~47a
C2 B5~B8 25b~27b
C4 B15~B18 45b~47b
y
x
z

FIG. 8B

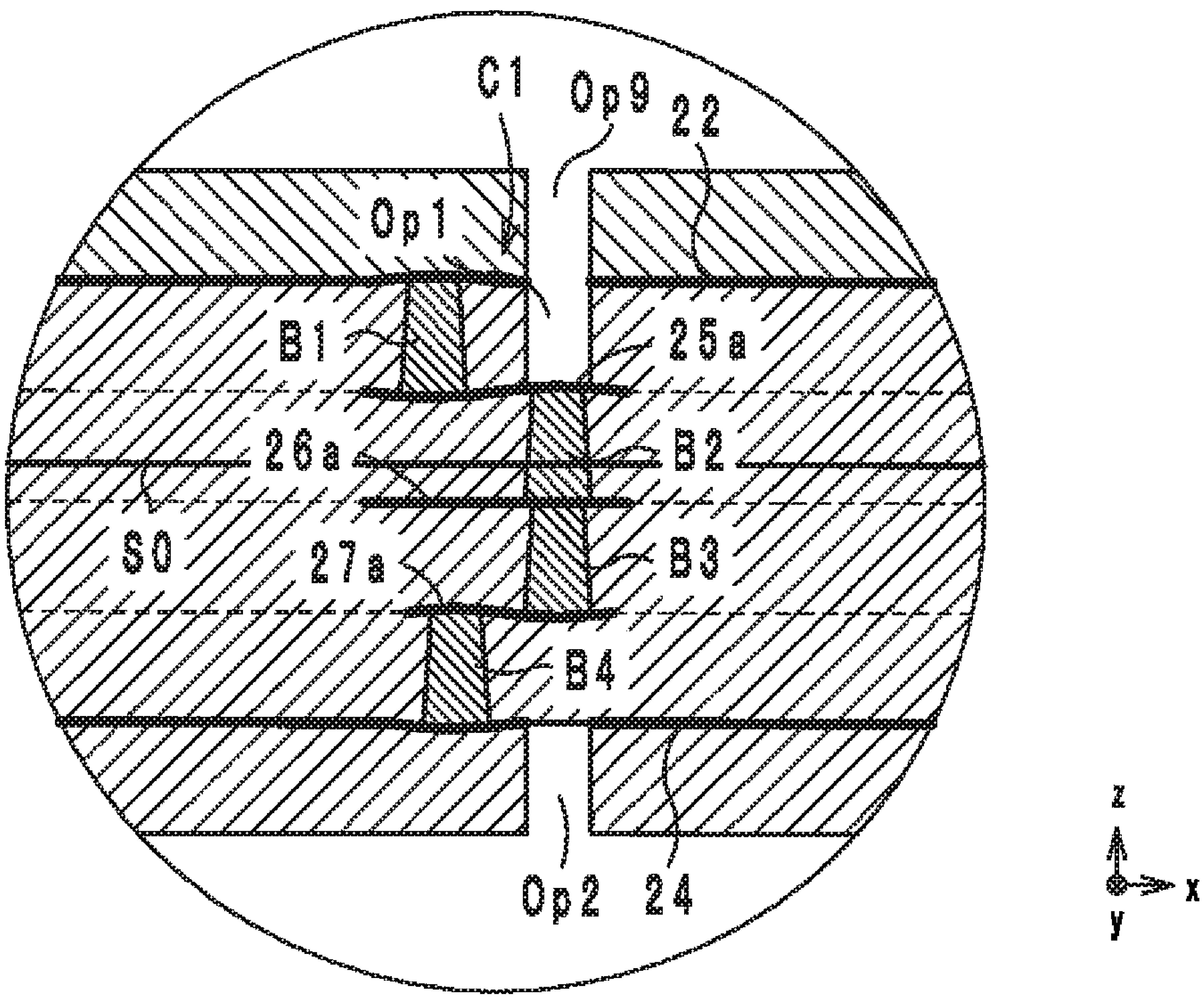


FIG. 8C

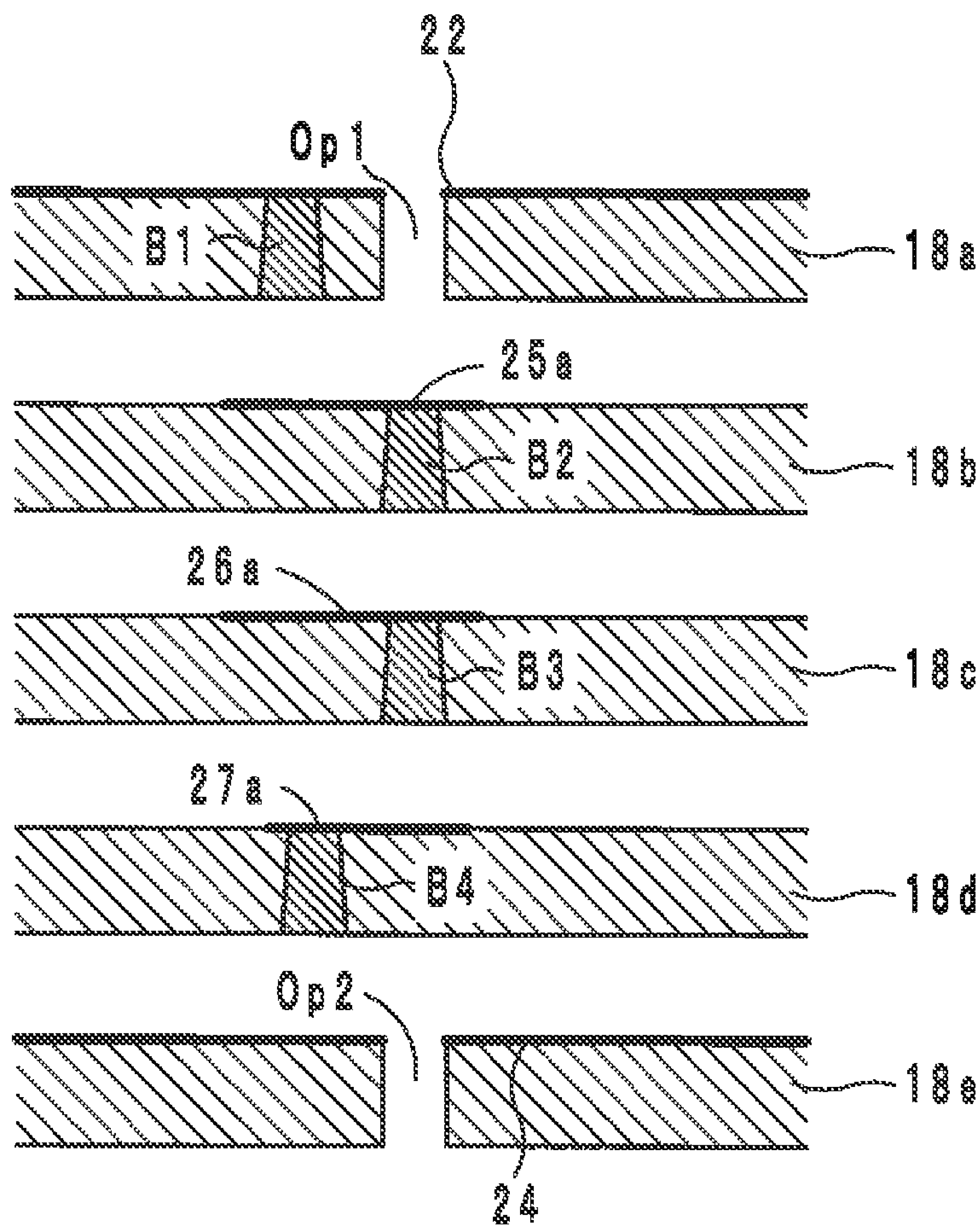
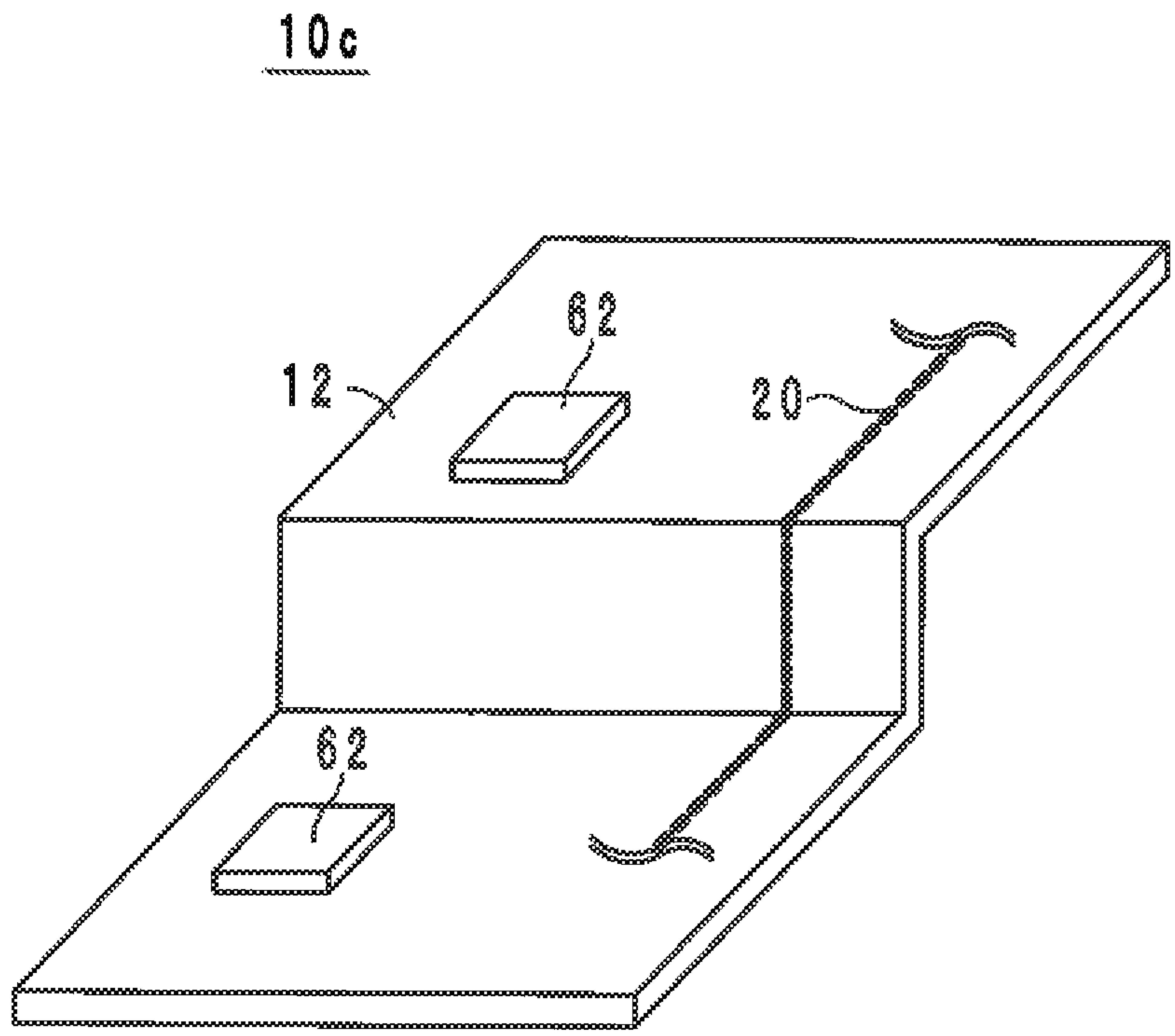


FIG. 9



HIGH-FREQUENCY SIGNAL TRANSMISSION LINE AND ELECTRONIC DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a high-frequency signal transmission line and an electronic device, and more particularly to a high-frequency signal transmission line preferably for use in high-frequency signal transmission and an electronic device.

2. Description of the Related Art

As a conventional high-frequency signal transmission line, for example, a signal line disclosed in WO 2011/007660 is known. The signal line disclosed in WO 2011/007660 includes a stacked body, a signal line, a first ground conductor, a second ground conductor, and via-hole conductors. The stacked body is a stack of insulating layers. The signal line is a linear conductor provided in the stacked body. The first ground conductor and the second ground conductor are stacked together with the insulating layers so as to face each other across the signal line. Accordingly, the signal line and the first and the second ground conductors form a stripline structure. The via-hole conductors are pierced in the insulating layers so as to connect the first ground conductor to the second ground conductor.

The signal line disclosed in WO 2011/007660 has a problem that the stacked body is hard to bend. Specifically, in the signal line disclosed in WO 2011/007660, a plurality of via-hole conductors are connected so as to be arranged straight in a stacking direction and configure a cylinder. The via-hole conductors connected straight to configure a cylinder are not flexible, and these via-hole conductors hinder bending of the stacked body.

SUMMARY OF THE INVENTION

Preferred embodiments of the present invention provide a high-frequency signal transmission line that is easy to bend, and an electronic device.

A high-frequency signal transmission line according to a first aspect of various preferred embodiments of the present invention is a high-frequency signal transmission line that is bent when used. The high-frequency signal transmission line includes a body including dielectric layers stacked on top of one another; a signal line provided in the body; a first ground conductor located at one side in a stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; a second ground conductor located at another side in the stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; and a connection portion including a plurality of interlayer connection conductors, each of the interlayer connection conductors pierced in one of the dielectric layers, and a plurality of connection conductors, each of the connection conductors provided on one of the dielectric layers, the connection portion configured to connect the first ground conductor to the second ground conductor, wherein two of the interlayer connection conductors that constitute both ends in the stacking direction of the connection portion are located farther away from a center of a bending section where the body is to be bent than the other interlayer connection conductors of the connection portion; and openings are located respectively in ones of the dielectric layers located at the one side and the another side in the stacking direction in relation to the other interlayer connection conductors, at positions that overlap with the other interlayer connection conductors.

A high-frequency signal transmission line according to a second aspect of various preferred embodiments of the present invention is a high-frequency signal transmission line that is bent when used. The high-frequency signal transmission line includes a body including dielectric layers stacked on top of one another; a signal line provided in the body; a first ground conductor located at a side in a stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; a second ground conductor located at another side in the stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; and a connection portion including a plurality of interlayer connection conductors, each of the interlayer connection conductors pierced in one of the dielectric layers, and a plurality of connection conductors, each of the connection conductors provided on one of the dielectric layers, the connection portion configured to connect the first ground conductor to the second ground conductor, wherein two of the interlayer connection conductors that constitute both ends in the stacking direction of the connection portion are located farther away from a center of a bending section where the body is to be bent than another of the interlayer connection conductors of the connection portion crossing a neutral surface of the bending section.

An electronic device according to the second aspect of various preferred embodiments of the present invention includes an article, and a high-frequency signal transmission line that is bent when used. The high-frequency signal transmission line includes a body including dielectric layers stacked on top of one another; a signal line provided in the body; a first ground conductor located at one side in a stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; a second ground conductor located at another side in the stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; and a connection portion including a plurality of interlayer connection conductors, each of the interlayer connection conductors pierced in one of the dielectric layers, and a plurality of connection conductors, each of the connection conductors provided on one of the dielectric layers, the connection portion configured to connect the first ground conductor to the second ground conductor, wherein two of the interlayer connection conductors that constitute both ends in the stacking direction of the connection portion are located farther away from a center of a bending section where the body is to be bent than another of the interlayer connection conductors of the connection portion crossing a neutral surface of the bending section; and a main surface of the body nearer the first ground conductor in relation to the signal line contacts with the article.

According to various preferred embodiments of the present invention, a dielectric body that is easy to bend is provided.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a perspective view of a high-frequency signal transmission line according to a preferred embodiment of the present invention.

FIG. **1**B is a perspective view of the high-frequency signal transmission line according to a preferred embodiment of the present invention.

FIG. **2** is an exploded view of a dielectric body of the high-frequency signal transmission line according to a preferred embodiment of the present invention.

FIG. **3**A is a sectional view of the high-frequency signal transmission line according to a preferred embodiment of the present invention.

FIG. **3**B is a sectional view of a stacked body used for derivation of a neutral surface.

FIG. **4**A is a perspective view of a connector of the high-frequency signal transmission line.

FIG. **4**B is a sectional view of the connector of the high-frequency signal transmission line.

FIG. **5**A is a plan view in a y-direction of an electronic device including the high-frequency signal transmission line.

FIG. **5**B is a plan view in a z-direction of the electronic device including the high-frequency signal transmission line.

FIG. **5**C is a sectional view of dielectric sheets before pressure bonding.

FIG. **6** is a sectional view of a connection portion of a high-frequency signal transmission line according to a comparative example.

FIG. **7** is a sectional view of a connection portion of a high-frequency signal transmission line.

FIG. **8**A is an exploded view of a dielectric body of a high-frequency signal transmission line.

FIG. **8**B is a sectional view of a connection portion of the high-frequency signal transmission line.

FIG. **8**C is a sectional view of dielectric sheets before pressure bonding.

FIG. **9** is a perspective view of a circuit board according to a modification of a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

High-frequency signal transmission lines and electronic devices according to preferred embodiments of the present invention will be described with reference to the drawings.

The structure of a high-frequency signal transmission line according to a preferred embodiment of the present invention is described with reference to the drawings. FIGS. **1**A and **1**B are perspective views of a high-frequency signal transmission line **10** according to a preferred embodiment of the present invention. FIG. **2** is an exploded view of a dielectric body **12** of the high-frequency signal transmission line **10**. FIG. **3**A is a sectional view of the high-frequency signal transmission line **10**. In the sectional view of FIG. **3**A, via-hole conductors B**1** through B**4** and B**11** through B**14** are at the same positions as via-hole conductors B**5** through B**8** and B**15** through B**18**, respectively, and connection conductors **25***a*, **26***a*, **27***a*, **45***a*, **46***a* and **47***a* are at the same positions as connection conductors **25***b*, **26***b*, **27***b*, **45***b*, **46***b* and **47***b*, respectively. In FIGS. **1** through **3**A, the stacking direction of the high-frequency signal transmission line **10** is defined as z-direction. The lengthwise direction of the high-frequency signal transmission line **10** is defined as x-direction. The direction orthogonal to the x-direction and the z-direction is defined as y-direction.

The high-frequency signal transmission line **10** is flexible, and the high-frequency signal transmission line **10** is bent when it is used. As illustrated in FIGS. **1**A through **3**, the high-frequency signal transmission line **10** includes a dielectric body **12**, external terminals **16***a* and **16***b*, a signal line **20**, ground conductors **22** and **24**, connection portions C**1** through C**4** (see FIG. **3**A), and connectors **100***a* and **100***b*.

When viewed from the z-direction, the dielectric body **12** extends in the x-direction, and includes a line portion **12***a*, and connecting portions **12***b* and **12***c*. The dielectric body **12** is, as illustrated in FIG. **2**, a flexible stacked body of a protective layer **14** and dielectric sheets (insulating layers) **18***a* through **18***e* stacked in this order from a positive side to a negative side in the z-direction. In the following, a main surface of the dielectric body **12** at the positive side in the z-direction is referred as a front surface, and a main surface of the dielectric body **12** at the negative side in the z-direction is referred as a back surface.

The line portion **12***a* extends in the x-direction. The connecting portions **12***b* and **12***c* preferably are rectangular or substantially rectangular portions connected to a positive end in the x-direction and a negative end in the x-direction, respectively, of the line portion **12***a*. The widths (sizes in the y-direction) of the connecting portions **12***b* and **12***c* are greater than the width (size in the y-direction) of the line portion **12***a*.

The dielectric sheets **18***a* through **18***e*, as seen in FIG. **2**, extend in the x-direction and have the same shape as the dielectric body **12** when viewed from the z-direction. The dielectric sheets **18***a* through **18***e* are formed of flexible thermoplastic resin such as polyimide, liquid polymer or the like. The thickness of each of the dielectric sheets **18***a* through **18***e* after pressure bonding preferably is, for example, within a range of about 10 μm to about 150 μm. In the following, a main surface of each of the dielectric sheets **18***a* through **18***e* at the positive side in the z-direction is hereinafter referred to as a front surface, and a main surface of each of the dielectric sheets **18***a* through **18***e* at the negative side in the z-direction is hereinafter referred to as a back surface.

The dielectric sheet **18***a* includes a line portion **18***a-a*, and connecting portions **18***a-b* and **18***a-c*. The dielectric sheet **18***b* includes a line portion **18***b-a*, and connecting portions **18***b-b* and **18***b-c*. The dielectric sheet **18***c* includes a line portion **18***c-a*, and connecting portions **18***c-b* and **18***c-c*. The dielectric sheet **18***d* includes a line portion **18***d-a*, and connecting portions **18***d-b* and **18***d-c*. The dielectric sheet **18***e* includes a line portion **18***e-a*, and connecting portions **18***e-b* and **18***e-c*. The line portions **18***a-a*, **18***b-a*, **18***c-a*, **18***d-a* and **18***e-a* constitute the line portion **12***a* of the dielectric body **12**. The connecting portions **18***a-b*, **18***b-b*, **18***c-b*, **18***d-b* and **18***e-b* constitute the connecting portion **12***b* of the dielectric body **12**. The connecting portions **18***a-c*, **18***b-c*, **18***c-c*, **18***d-c* and **18***e-c* constitute the connecting portion **12***c* of the dielectric body **12**.

As seen in FIGS. **1**A and **2**, the external terminal **16***a* is a rectangular or substantially rectangular conductor provided substantially in the center of the front surface of the connecting portion **18***a-b*. As seen in FIGS. **1**A and **2**, the external terminal **16***b* is a rectangular or substantially rectangular conductor provided substantially in the center of the front surface of the connecting portion **18***a-c*. The external terminals **16***a* and **16***b* are formed of a metal material with a low specific resistance containing mainly of silver or copper. The external terminals **16***a* and **16***b* are plated with gold.

As seen in FIG. **2**, the signal line **20** is a linear conductor embedded in the dielectric body **12**. Specifically, the signal line **20** is provided on the front surface of the dielectric sheet **18***d* so as to extend in the x-direction. Both ends of the signal line **20** are located to overlap with the external terminals **16***a* and **16***b*, respectively, when viewed from the z-direction. The signal line **20** is formed of a metal material with a low specific resistance containing mainly of silver or copper.

Via-hole conductors b**11**, b**13** and b**15** are pierced in the connecting portions **18***a-b*, **18***b-b*, **18***c-b* of the dielectric sheets **18***a*, **18***b* and **18***c*, respectively, in the z-direction. The via-hole conductors b**11**, b**13** and b**15** are connected so as to define one via-hole conductor. Accordingly, the via-hole conductors b**11**, b**13** and b**15** connect the external terminal **16***a* to the negative end in the x-direction of the signal line **20**.

Via-hole conductors b**12**, b**14** and b**16** are pierced in the connecting portions **18***a-c*, **18***b-c*, **18***c-c* of the dielectric sheets **18***a*, **18***b* and **18***c*, respectively, in the z-direction. The via-hole conductors b**12**, b**14** and b**16** are connected so as to define one via-hole conductor. Accordingly, the via-hole conductors b**12**, b**14** and b**16** connect the external terminal **16***b* to the negative end in the x-direction of the signal line **20**. The via-hole conductors b**11** through b**16** are formed of a metal material with a low specific resistance containing mainly of silver or copper.

As seen in FIGS. **2** and **3**A, the ground conductor **22** (first ground conductor) is provided in the dielectric body **12** and located farther in the positive z-direction than the signal line **20**. Specifically, the ground conductor **22** is provided on the front surface of the dielectric sheet **18***a*. The ground conductor **22** extends in the x-direction on the front surface of the dielectric sheet **18***a* so as to face the signal line **20** across the dielectric sheets **18***a* through **18***c*.

The ground conductor **22** includes a line portion **22***a*, and terminal portions **22***b* and **22***c*. The line portion **22***a* is provided on the front surface of the line portion **18***a-a* and extends in the x-direction. The line portion **22***a* has no substantial openings, and the line portion **22***a* is a continuous electrode provided in the line portion **12***a* to extend in the x-direction continuously along the signal line **20**. The line portion **22***a* of the ground conductor **22** does not necessarily cover the entire front surface of the line portion **12***a*. For example, micro holes may be provided in the line portion **22***a*, at predetermined positions, for escape of gas generated by thermocompression bonding of the dielectric sheets **18** formed of thermoplastic resin. The line portion **22***a* is formed of a metal material with a low specific resistance containing mainly of silver or copper.

The terminal portion **22***b* is provided on the front surface of the connecting portion **18***a-b*, and is shaped like a rectangular or substantially rectangular ring enclosing the external terminal **16***a*. The terminal portion **22***b* is connected to the negative end in the x-direction of the line portion **22***a*. The terminal portion **22***c* is provided on the front surface of the connecting portion **18***a-c*, and is shaped like a rectangular or substantially rectangular ring enclosing the external terminal **16***b*. The terminal portion **22***c* is connected to the positive end in the x-direction of the line portion **22***a*.

As seen in FIGS. **2** and **3**A, the ground conductor **24** (second ground conductor) extends in the x-direction along the signal line **20**. Specifically, the ground conductor **24** is provided in the dielectric body **12** and located farther in the negative z-direction than the signal line **20**. More specifically, the ground conductor **24** is provided on the front surface of the dielectric sheet **18***e*. The ground conductor **24** extends in the x-direction on the front surface of the dielectric sheet **18***e* so as to face the signal line **20** across the dielectric sheet **18***d*. The ground conductor **24** is formed of a metal material with a low specific resistance containing mainly of silver or copper.

The ground conductor **24** includes a line portion **24***a*, and terminal portions **24***b* and **24***c*. The line portion **24***a* is provided on the front surface of the line portion **18***a-e* and extends in the x-direction. The line portion **24***a* includes openings **30**, which are non-conductive portions, and bridges **60**, which are conductive portions, arranged alternately at uniform or substantially uniform intervals along the signal line **20**. Accordingly, the line portion **24***a* is shaped like a ladder. As seen in FIG. **2**, the openings **30** overlap with the signal line **20** when viewed from the z-direction. Thus, when viewed from the z-direction, the signal line **20** is overlapped with the openings **30** and the bridges **60** alternately.

Now, the shape of each of the openings **30** is described. Each of the openings **30** includes opening portions **30***a* through **30***c*. The opening portion **30***b* is a rectangular or substantially rectangular opening portion extending in the x-direction. The opening portion **30***a* is a rectangular or substantially rectangular opening portion connected to the negative end in the x-direction of the opening portion **30***b*. The opening portion **30***c* is a rectangular or substantially rectangular opening portion connected to the positive end in the x-direction of the opening portion **30***b*. The width (size in the y-direction) W**1** of the opening portion **30***b* is greater than the widths (sizes in the y-direction) W**2** of the opening portions **30***a* and **30***c*. Accordingly, each of the openings **30** is shaped like a cross. When viewed from the z-direction, the signal line **20** crosses the centers of the openings **30** in the y-direction.

In the high-frequency signal transmission line **10**, areas in which the opening portions **30***b* are located are referred to as areas A**1**, and areas in which the bridges **60** are located are referred to as areas A**2**. Areas in which the opening portions **30***a* are located are referred to as areas A**3**, and areas in which the opening portions **30***c* are located are referred to as areas A**4**.

The terminal portion **24***b* is provided on the front surface of the connecting portion **18***e-b*, and is shaped like a rectangular or substantially rectangular ring enclosing the center of the connecting portion **18***e-b*. The terminal portion **24***b* is connected to the negative end in the x-direction of the line portion **24***a*.

The terminal portion **24***c* is provided on the front surface of the connecting portion **18***e-c*, and is shaped like a rectangular or substantially rectangular ring enclosing the center of the connecting portion **18***e-c*. The terminal portion **24***c* is connected to the positive end in the x-direction of the line portion **24***a*.

As indicated in FIG. **2**, the line width Wa of the signal line **20** in the areas A**1** is greater than the line width Wb of the signal line **20** in the areas A**2**, A**3** and A**4**. In the areas A**1**, the distance between the signal line **20** and the ground conductor **24** is greater, and therefore, in order to reduce the resistance of the signal line **20** to a high-frequency wave (conductor loss), the line width of the signal line **20** is increased to Wa. In the areas A**2**, A**3** and A**4**, on the other hand, the distance between the signal line **20** and the ground conductor **24** is smaller, and therefore, in order to prevent a reduction in the impedance of the signal line **20**, the line width of the signal line **20** is decreased to Wb.

Next, the connection portions C**1** through C**4** are described. As mentioned, the high-frequency signal transmission line **10** is bent when used. In the following paragraphs, a section where the dielectric body **12** of the high-frequency signal transmission line **10** to be bent is referred to as a section D. The dielectric body **12** is to be bent such that the section D protrudes in the negative z-direction. The center in the x-direction of the section D is referred to as a center of bend.

The connection portion C**1** connects the line portion **22***a* of the ground conductor **22** to the line portion **24***a* of the ground conductor **24**. The connection portion C**1** includes via-hole conductors (interlayer connection conductors) B**1** through B**4** and connection conductors **25***a* through **27***a* connected to each other. As seen in FIG. **2**, the connection portion C**1** is located in the section D and farther in the negative x-direction than the center of bend. Also, the connection portion C**1** is located farther in the positive y-direction than the signal line **20**.

The via-hole conductor B**1** is pierced in the line portion **18***a-a* of the dielectric sheet **18***a* in the z-direction, at a position farther in the positive y-direction than the signal line **20**. The via-hole conductor B**2** is pierced in the line portion **18***b-a* of the dielectric sheet **18***b* in the z-direction, at a position farther in the positive y-direction than the signal line **20**. The central axis of the via-hole conductor B**2** is located farther in the positive x-direction than the central axis of the via-hole conductor B**1**. The via-hole conductor B**3** is pierced in the line portion **18***c-a* of the dielectric sheet **18***c* in the z-direction, at a position farther in the positive y-direction than the signal line **20**. The central axis of the via-hole conductor B**3** is located at the same position as the central axis of the via-hole conductor B**2** and accordingly located farther in the positive x-direction than the central axis of the via-hole conductor B**1**. The via-hole conductor B**4** is pierced in the line portion **18***d-a* of the dielectric sheet **18***d* in the z-direction, at a position farther in the positive y-direction than the signal line **20**. The central axis of the via-hole conductor B**4** is located farther in the negative x-direction than the central axes of the via-hole conductors B**2** and B**3**. The via-hole conductors B**1** through B**4** are formed of a metal material with a low specific resistance containing mainly of silver or copper.

The connection conductor **25***a* is provided on the line portion **18***b-a* of the dielectric sheet **18***b*, at a position farther in the positive y-direction than the signal line **20**. The connection conductor **25***a* is in the shape of a rectangle extending in the x-direction and connects the via-hole conductor B**1** to the via-hole conductor B**2**. The negative end in the z-direction of the via-hole conductor B**1** contacts with the negative end portion in the x-direction of the connection conductor **25***a*. The positive end in the z-direction of the via-hole conductor B**2** contacts with the positive end portion in the x-direction of the connection conductor **25***a*.

The connection conductor **26***a* is provided on the line portion **18***c-a* of the dielectric sheet **18***c*, at a position farther in the positive y-direction than the signal line **20**. The connection conductor **26***a* is in the shape of a rectangle extending in the x-direction and connects the via-hole conductor B**2** to the via-hole conductor B**3**. The negative end in the z-direction of the via-hole conductor B**2** contacts with the positive end portion in the x-direction of the connection conductor **26***a*. The positive end in the z-direction of the via-hole conductor B**3** contacts with the positive end portion in the x-direction of the connection conductor **26***a*.

The connection conductor **27***a* is provided on the line portion **18***d-a* of the dielectric sheet **18***d*, at a position farther in the positive y-direction than the signal line **20**. The connection conductor **27***a* is L-shaped and connects the via-hole conductor B**3** to the via-hole conductor B**4**. The negative end in the z-direction of the via-hole conductor B**3** contacts with the positive end portion in the x-direction of the connection conductor **27***a*. The positive end in the z-direction of the via-hole conductor B**4** contacts with the negative end portion in the x-direction of the connection conductor **27***a*.

In the connection portion C**1**, as seen in FIG. **3**A, the via-hole conductors B**1** and B**4** that constitute both ends in the z-direction of the connection portion C**1** are located farther away from the center of bend than the other via-hole conductors B**2** and B**3** of the connection portion C**1**. The ground conductor **22** is located near the front surface of the dielectric body **12**, and the ground conductor **24** is located near the back surface of the dielectric body **12**. Therefore, a neutral surface S**0** is located between the ground conductors **22** and **24**. The neutral surface S**0** is a surface on which no compression stress and no tensile stress act when the dielectric body **12** is bent at the section D. The via-hole conductors B**1** through B**4** have the same or substantially the same length, and the neutral surface S**0** crosses the via-hole conductor B**2** as illustrated in FIG. **3**A. In this preferred embodiment, the via-hole conductors B**1** and B**4** that constitute the both ends in the z-direction of the connection portion C**1** are located farther away from the center of bend than the via-hole conductor B**2** crossing the neutral surface S**0**.

For reference, derivation of the position of the neutral surface of a stacked body of insulating layers made of some kinds of materials, such as the dielectric body **12**, is described with reference to the drawings. FIG. **3**B is a sectional view of a stacked body **300** that was used for derivation of the neutral surface. In FIG. **3**B, the stacking direction is defined as y-direction. The positive y-direction is a downward direction along the stacking direction as indicated in FIG. **3**B.

The stacked body **300** includes n insulating layers stacked on top of one another. If the Young's modulus of the ith layer is denoted by Ei and the y-coordinate of the border between the ith insulating layer and the (i+1)th insulating layer is denoted by li, the y-coordinate Y**0** of the neutral surface is expressed as follows.

$$Y0 = \frac{\sum_{i=1}^{n} Ei \int_{li-1}^{li} y\,dA}{\sum_{i=1}^{n} Ei \int_{li-1}^{li} dA} = \frac{\left\{\sum_{i=1}^{n} Ei(l_i^2 - l_{i-1}^2)\right\}}{2\sum_{i=1}^{n} Ei(l_i - l_{i-1})} \tag{1}$$

By using the expression (1), the position of the neutral surface S**0** of the dielectric body **12** is derived.

The connection portion C**2** connects the line portion **22***a* of the ground conductor **22** to the line portion **24***a* of the ground conductor **24**. The connection portion C**2** includes via-hole conductors B**5** through B**8** and connection conductors **25***b* through **27***b* connected to each other. As indicated in FIG. **2**, the connection portion C**2** is line-symmetrical or substantially line-symmetrical to the connection portion C**1** with respect to the signal line **20**, and a detailed description of the connection portion C**2** is omitted.

The connection portion C**3** connects the line portion **22***a* of the ground conductor **22** to the line portion **24***a* of the ground conductor **24**. The connection portion C**3** includes via-hole conductors (interlayer connection conductors) B**11** through B**14** and connection conductors **45***a* through **47***a* connected to each other. As seen in FIG. **2**, the connection portion C**3** is located in the bending section D and farther in the positive x-direction than the center of bend. The connection portion C**3** is located farther in the positive y-direction than the signal line **20**.

The via-hole conductor B**11** is pierced in the line portion **18***a-a* of the dielectric sheet **18***a* in the z-direction, at a position farther in the positive y-direction than the signal line **20**. The via-hole conductor B**12** is pierced in the line portions **18***b-a* of the dielectric sheet **18***b* in the z-direction, at a position farther in the positive y-direction than the signal line **20**. The central axis of the via-hole conductor B**12** is located farther in the negative x-direction than the central axis of the via-hole conductor B**11**. The via-hole conductor B**13** is pierced in the line portion **18***c-a* of the dielectric sheet **18***c* in the z-direction, at a position farther in the positive y-direction than the signal line **20**. The central axis of the via-hole conductor B**13** is located at the same position as the central axis of the via-hole conductor B**12** and accordingly located farther in the negative x-direction than the central axis of the via-hole conductor B**11**. The via-hole conductor B**14** is pierced in the line portion **18***d-a* of the dielectric sheet **18***d* in the z-direction, at a position farther in the positive y-direction than the signal line **20**. The central axis of the via-hole conductor B**14** is located farther in the positive x-direction than the central axes of the via-hole conductors B**12** and B**13**. The via-hole conductors B**11** through B**14** are formed of a metal material with a low specific resistance containing mainly of silver or copper.

The connection conductor **45***a* is provided on the line portion **18***b-a* of the dielectric sheet **18***b*, at a position farther in the positive y-direction than the signal line **20**. The connection conductor **45***a* is in the shape of a rectangle extending in the x-direction and connects the via-hole conductor B**11** to the via-hole conductor B**12**. The negative end in the z-direction of the via-hole conductor B**11** contacts with the positive end portion in the x-direction of the connection conductor **45***a*. The positive end in the z-direction of the via-hole conductor B2 contacts with the negative end portion in the x-direction of the connection conductor **45***a*.

The connection conductor **46***a* is provided on the line portion **18***c-a* of the dielectric sheet **18***c*, at a position farther in the positive y-direction than the signal line **20**. The connection conductor **46***a* is in the shape of a rectangle extending in the x-direction and connects the via-hole conductor B**12** to the via-hole conductor B**13**. The negative end in the z-direction of the via-hole conductor B**12** contacts with the negative end portion in the x-direction of the connection conductor **46***a*. The positive end in the z-direction of the via-hole conductor B**13** contacts with the negative end portion in the x-direction of the connection conductor **46***a*.

The connection conductor **47***a* is provided on the line portion **18***d-a* of the dielectric sheet **18***d*, at a position farther in the positive y-direction than the signal line **20**. The connection conductor **47***a* is L-shaped and connects the via-hole conductor B**13** to the via-hole conductor B**14**. The negative end in the z-direction of the via-hole conductor B**13** contacts with the negative end portion in the x-direction of the connection conductor **47***a*. The positive end in the z-direction of the via-hole conductor B**14** contacts with the positive end portion in the x-direction of the connection conductor **47***a*.

In the connection portion C**3**, as seen in FIG. **3**A, the via-hole conductors B**11** and B**14** that constitute both ends in the z-direction of the connection portion C**3** are located farther away from the center of bend than the other via-hole conductors B**12** and B**13**. In this preferred embodiment, the via-hole conductors B**11** and B**14** that constitute the both ends in the z-direction of the connection portion C**3** are located farther away from the center of bend than the via-hole conductor B**12** crossing the neutral surface S**0**.

The connection portion C**4** connects the line portion **22***a* of the ground conductor **22** to the line portion **24***a* of the ground conductor **24**. The connection portion C**4** includes via-hole conductors B**15** through B**18** and connection conductors **45***b* through **47***b* connected to each other. As indicated in FIG. **2**, the connection portion C**4** is line-symmetrical or substantially line-symmetrical to the connection portion C**3** with respect to the signal line **20**, and a detailed description of the connection portion C**4** is omitted.

The connection portions C**1** through C**4** contact with the ground conductor **24** in the areas A**2** between the openings **30**. More specifically, the negative ends in the z-direction of the via-hole conductors B**4**, B**8**, B**14** and B**18** contact with the bridges **60**.

As thus far described, the signal line **20** and the ground conductors **22** and **24** define a triplate-type stripline structure. The distance between the signal line **20** and the ground conductor **22** is equal or substantially equal to the total of the thicknesses of the dielectric sheets **18***a* through **18***c* and is, for example, within a range of about 50 μm to about 300 μm. In this preferred embodiment, the distance between the signal line **20** and the ground conductor **22** preferably is about 150 μm. The distance between the signal line **20** and the ground conductor **24** is equal or substantially equal to the thickness of the dielectric sheet **18***d*, and for example, within a range of about 10 μm to about 150 μm. In this preferred embodiment, the distance between the signal line **20** and the ground conductor **24** preferably is about 50 μm. Thus, the dielectric sheets **18***a* through **18***d* are designed such that the total of the thicknesses of the dielectric sheets **18***a* through **18***c* is greater than the thickness of the dielectric sheet **18***d*. The widths (sizes in the y-direction) of the ground conductors **22** and **24** preferably are, for example, about 800 μm. Thus, the high-frequency signal transmission line **10** is a thin and wide high-frequency signal transmission line.

The protective layer **14** covers substantially the entire front surface of the dielectric sheet **18***a*. Accordingly, the protective layer **14** covers the ground conductor **22**. The protective layer **14** is formed of flexible resin, such as a resist material, for example.

As seen in FIG. **2**, the protective layer **14** includes a line portion **14***a*, and connecting portions **14***b* and **14***c*. The line portion **14***a* covers the entire front surface of the line portion **18***a-a* of the dielectric sheet **18***a* and accordingly covers the line portion **22***a* of the ground conductor **22**.

The connecting portion **14***b* is connected to the negative end in the x-direction of the line portion **14***a* and covers the front surface of the connecting portion **18***a-b*. However, the connecting portion **14***b* includes openings Ha through Hd. The opening Ha is a rectangular or substantially rectangular opening located substantially in the center of the connecting portion **14***b*. The external terminal **16***a* is exposed to outside through the opening Ha. The opening Hb is a rectangular or substantially rectangular opening located farther in the positive y-direction than the opening Ha. The opening Hc is a rectangular or substantially rectangular opening located farther in the negative x-direction than the opening Ha. The opening Hd is a rectangular or substantially rectangular opening located farther in the negative y-direction than the opening Ha. The terminal portion **22***b* is exposed to outside through the openings Hb through Hd and defines and functions as an external terminal.

The connecting portion **14***c* is connected to the positive end in the x-direction of the line portion **14***a* and covers the front surface of the connecting portion **18***a-c*. However, the connecting portion **14***c* includes openings He through Hh. The opening He is a rectangular or substantially rectangular opening located substantially in the center of the connecting portion **14***c*. The external terminal **16***b* is exposed to outside through the opening He. The opening Hf is a rectangular or substantially rectangular opening located farther in the positive y-direction than the opening He. The opening Hg is a rectangular or substantially rectangular opening located farther in the positive x-direction than the opening He. The opening Hh is a rectangular or substantially rectangular opening located farther in the negative y-direction than the opening He. The terminal portion **22***c* is exposed to outside through the openings Hf through Hh and functions as an external terminal.

The connectors **100***a* and **100***b* are mounted on the front surfaces of the connecting portions **12***b* and **12***c*, respectively, and are electrically connected to the signal line **20** and the ground conductors **22** and **24**. The connectors **100***a* and **100***b* preferably have the same structure, and the structure of the connector **100***b* is described below as an example. FIG. **4**A is a perspective view of the connector **100***b* of the high-frequency signal transmission line **10**. FIG. **4**B is a sectional view of the connector **100***b* of the high-frequency signal transmission line **10**.

The connector **100***b*, as illustrated in FIGS. **4**A and **4**B, includes a connector body **102**, external terminals **104** and **106**, a central conductor **108** and an external conductor **110**. The connector body **102** is in the shape of a rectangular or substantially rectangular plate with a cylinder connected thereon, and is formed of an insulating material such as resin.

The external terminal **104** is provided on the surface of the plate-shaped portion of the connector body **102** at the negative side in the z-direction so as to face the external terminal **16***b*. The external terminal **106** is provided on the surface of the plate-shaped portion of the connector body **102** at the negative side in the z-direction so as to face the terminal portion **22***c* exposed through the openings Hf through Hh.

The central conductor **108** is located in the center of the cylindrical portion of the connector body **102** and is connected to the external terminal **104**. The central conductor **108** is a signal terminal at which a high-frequency signal is input or output. The external conductor **110** is provided on the inner surface of the cylindrical portion of the connector body **102** and is connected to the external terminal **106**. The external conductor **110** is aground terminal that is maintained at aground potential.

The connector **100***b* having the structure above is mounted on the front surface of the connecting portion **12***c* such that the external terminal **104** is connected to the external terminal **16***b* and such that the external terminal **106** is connected to the terminal portion **22***c*. Thus, the signal line **20** is electrically connected to the central conductor **108**, and the ground conductors **22** and **24** are electrically connected to the external conductor **110**.

The high-frequency signal transmission line **10** is preferably used in the following way. FIG. **5**A is a plan view from the y-direction of an electronic device **200** including the high-frequency signal transmission line **10**. FIG. **5**B is a plan view from the z-direction of the electronic device **200** including the high-frequency signal transmission line **10**.

The electronic device **200** includes the high-frequency signal transmission line **10**, circuit boards **202***a* and **202***b*, receptacles **204***a* and **204***b*, a battery pack (an article) **206**, and a case **210**.

In the circuit board **202***a*, for example, a transmitting circuit or a receiving circuit including an antenna is provided. In the circuit board **202***b*, for example, a feed circuit is provided. The battery pack **206** is, for example, a lithium-ion secondary battery, and the surface of the battery pack **206** is covered by a metal cover. The circuit board **202***a*, the battery pack **206** and the circuit board **202***b* are arranged in this order from the negative side to the positive side in the x-direction.

The front surface of the dielectric body **12** (the main surface nearer the ground conductor **22** in relation to the signal line **20**) is in contact with the battery **206**, and the dielectric body **12** is fixed to the battery pack **206** by an adhesive. The back surface of the dielectric body **12** faces the inner surface of the case **210** with a predetermined space.

The receptacles **204***a* and **204***b* are provided on respective main surfaces of the circuit boards **202***a* and **202***b* at the negative side in the z-direction. The connectors **100***a* and **100***b* are connected to the receptacles **204***a* and **204***b* respectively. Thus, a high-frequency signal with a frequency of, for example, about 2 GHz transmitted between the circuit boards **202***a* and **202***b* is applied to the central conductors **108** of the connectors **100***a* and **100***b* through the receptacles **204***a* and **204***b*. The respective external conductors **110** of the connectors **100***a* and **100***b* are maintained at the ground potential through the circuit boards **202***a* and **202***b*, and the receptacles **204***a* and **204***b*. In this way, the high-frequency signal transmission line **10** connects the circuit boards **202***a* and **202***b* to each other.

There are level differences between the main surface of the battery pack **206** at the negative side in the z-direction and each of the receptacles **204***a* and **204***b*. Therefore, by bending near the both end of the line portion **12***a* of the dielectric body **12**, it becomes possible to connect the connectors **100***a* and **100***b* to the receptacles **204***a* and **204***b*, respectively. In the electronic device **200** according to this preferred embodiment, the dielectric body **12** is bent at two positions, and as illustrated in FIG. **2**, there are two bending sections D near the both ends of the dielectric body **12**. As illustrated in FIG. **5**A, the connection portions **C1** through **C4** are provided in each of the bending sections D.

A non-limiting example of a manufacturing method of the high-frequency signal transmission line **10** is described below with reference to FIGS. **2** and **3**A through **5**C. FIG. **5**C is a sectional view of the dielectric sheets **18***a* through **18***e* before pressure bonding. A manufacturing method of one high-frequency signal transmission line **10** is described below as an example. Practically, however, a plurality of high-frequency signal transmission lines **10** are manufactured at one time by stacking large-sized dielectric sheets on top of one another and cutting the stacked body.

First, dielectric sheets, each formed of thermoplastic resin and including a copper foil (metal film) formed entirely on the front surface, are prepared as the dielectric sheets **18***a* through **18***e*. Specifically, copper foils are applied to respective one main surface of the dielectric sheets **18***a* through **18***c*. The surfaces of the copper foils are, for example, galvanized for corrosion proof and thus are smoothened. The thicknesses of the copper foils are preferably within a range of about 10 μm to about 50 μm, for example.

Next, the ground conductor **22** and the external terminals **16***a* and **16***b* and as illustrated in FIG. **2** are formed on the front surface of the dielectric sheet **18***a* by a photolithography process. Specifically, resists having identical shapes to the external terminals **16***a* and **16***b*, and the ground conductor **22** are printed on the copper foil on the dielectric sheet **18***a*. Then, the copper foil is etched, so that the portions of the copper foil not covered by the resists are removed. Thereafter, the resists are removed. In this way, the ground conductor **22** and the external terminals **16***a* and **16***b* as illustrated in FIG. **2** are formed on the front surface of the dielectric sheet **18***a*.

Next, the connection conductors **25***a*, **25***b*, **45***a* and **45***b* as illustrated in FIG. **2** are formed on the front surface of the dielectric sheet **18***b* by a photolithography process. The connection conductors **26***a*, **26***b*, **46***a* and **46***b* as illustrated in FIG. **2** are formed on the front surface of the dielectric sheet **18***c* by a photolithography process. The signal line **20** and the connection conductors **27***a*, **27***b*, **47***a* and **47***b* as illustrated in FIG. **2** are formed on the front surface of the dielectric sheet **18***d* by a photolithography process. The ground conductor **24** as illustrated in FIG. **2** is formed on the front surface of the dielectric sheet **18***e* by a photolithography process. These photolithography processes are the same as the photolithography process for forming the main ground conductor **22** and the external terminals **16***a* and **16***b*, and descriptions of the processes are omitted here.

Next, the dielectric sheets **18***a* through **18***d* are exposed to laser beams from their respective back surfaces such that through holes are made in the dielectric sheets **18***a* through **18***d* at the positions of the via-hole conductors B**1** through B**8**, B**11** through B**18** and b**11** through b**16**. Thereafter, conductive paste is filled in the through holes.

Next, the dielectric sheets **18***a* through **18***e* are stacked in this order from the positive side to the negative side in the z-direction as illustrated in FIG. **5**C. Next, heat and pressure are applied to the stacked body of the dielectric sheets **18***a* through **18***e* from the positive and negative sides in the z-direction. Thus, the dielectric sheets **18***a* through **18***e* are softened and bonded together, and the conductive paste filled in the through holes are hardened (metallized) to define the via-hole conductors B**1** through B**8**, B**11** through B**18** and b**11** through b**16**. In this moment, as illustrated in FIG. **3**A, the connection conductors **25***a*, **27***a*, **25***b*, **27***b*, **45***a*, **47***a*, **45***b*, and **47***b* are pressed by the via-hole conductors B**1** through B**8** and B**11** through B**18** to become wavy. The dielectric sheets **18***a* through **18***e* are not necessarily joined by pressure bonding and may be joined alternatively by an adhesive such as an epoxy resin adhesive. It is not always necessary to form the via-hole conductors B**1** through B**8** and B**11** through B**18** by filling the through holes entirely with a conductor, and for example, it is possible to form the via-hole conductors B**1** through B**8** and B**11** through B**18** by forming a conductor only along the inner surface of each of the through holes.

Lastly, resin (resist) paste is applied to the front surface of the dielectric sheet **18***a* to form the protective layer **14**.

In the high-frequency signal transmission line **10** having the structure above, the dielectric body **12** is easy to bend. Specifically, in the signal line disclosed in WO 2011/007660, a plurality of via-hole conductors are connected so as to be arranged straight in a stacking direction and define a cylinder. The via-hole conductors connected straight to define a cylinder are not flexible, and these via-hole conductors hinder bending of the stacked body.

In the high-frequency signal transmission line **10**, on the other hand, the connection portions C**1** through C**4** have such a structure not to hinder bending of the dielectric body **12**. Specifically, in the connection portion C**1**, the via-hole conductors B**1** through B**4** are connected not to be arranged straight in the z-direction. More specifically, the central axes of the via-hole conductors B**1** and B**4** are not at the same position in the x-direction as the central axes of the via-hole conductors B**2** and B**4**. The negative end in the z-direction of the via-hole conductor B**1** is connected to the positive end in the z-direction of the via-hole conductor B**2** via the connection conductor **25***a*. The negative end in the z-direction of the via-hole conductor B**3** is connected to the positive end in the z-direction of the via-hole conductor B**4** via the connection conductor **27***a*. Unlike the via-hole conductors B**1** through B**4**, the connection conductors **25***a* and **27***a* are thin conductor layers. Accordingly, the connection conductors **25***a* and **27***a* are flexible compared with the via-hole conductors B**1** through B**4**. Therefore, when the dielectric body **12** is bent, the connection conductors **25***a* and **27***a* change their shapes. Thus, the connection portion C**1** is configured to not hinder bending of the dielectric body **12**. Consequently, the dielectric body **12** is easy to bend. The same applies to the connection portions C**2** through C**4**.

In the high-frequency signal transmission line **10**, the dielectric body **12** is easy to bend also for the reason below. Specifically, when the dielectric body **12** is bent, no compression stress and no tensile stress act on the neutral surface S**0**. Also, closer to the outer periphery from the neutral surface S**0**, a greater tensile stress acts, and closer to the inner periphery from the neutral surface S**0**, a greater compression stress acts. Also, in the section D where the dielectric body **12** is bent, closer to the center of bend from either end of the section D, a greater stress acts. Therefore, it is not good to locate inflexible via-hole conductors near the center of bend, near the front surface or the back surface of the dielectric body **12**.

In view of the above, in the high-frequency signal transmission line **10**, the via-hole conductors B**1** and B**4** that constitute the both ends in the z-direction of the connection portion C**1** are located farther away from the center of bend than the other via-hole conductors B**2** and B**3** of the connection portion C**1**. Accordingly, the via-hole conductors B**1** and B**4** are located farther away from the center of bend than the via-hole conductor B**2** crossing the neutral surface S**0**. With this arrangement, the via-hole conductors B**1** and B**4** are not located at positions where great stresses act, and it becomes less likely that the via-hole conductors B**1** and B**4** hinder bending of the dielectric body **12**. For the reasons above, it is easy to bend the dielectric body **12** of the high-frequency signal transmission line **10**. The same applies to the connection portions C**2** through C**4**.

In the high-frequency signal transmission line **10**, also, it is unlikely that the portions where the connection portions C**1** and C**2** are provided protrude from the front surface or the back surface of the dielectric body **12**. FIG. **6** is a sectional view of a connection portion C**600** of a high-frequency signal transmission line **610** according to a comparative example.

In the high-frequency signal transmission line **610** illustrated in FIG. **6**, in the connection portion C**600**, via-hole conductors B**601** through B**604** are connected to define a straight line. The via-hole conductors B**601** through B**604** are harder than dielectric sheets **618***a* through **618***e*, and at the time of thermocompression bonding of the dielectric sheets **618***a* through **618***e*, the via-hole conductors B**601** through B**604** protrude from the front surface and the back surface of the high-frequency signal transmission line **610**.

In the high-frequency signal transmission line **10**, on the other hand, in the connection portion C**1**, the central axes of the via-hole conductors B**1** and B**4** are not at the same position as the via-hole conductors B**2** and B**3**. In other words, in the high-frequency signal transmission line **10**, the via-hole conductors B**1** through B**4** are not arranged in a straight line. This arrangement reduces or prevents protrusion of the portions where the connection portion C**1** is provided from the front surface or the back surface of the dielectric body **12**. The same applies to the connection portions C**2** through C**4**.

In the high-frequency signal transmission line **10**, also, when the dielectric body **12** is bent, the connection conductors **25***a* through **27***a*, **25***b* through **27***b*, **45***a* through **47***a* and **45***b* through **47***b* deform, which prevents great forces from acting on the via-hole conductors B**1** through B**8** and B**11** through B**18**. Accordingly, it is unlikely that the resilience of the deformed via-hole conductors B**1** through B**8** and B**11** through B**18** is transmitted to the dielectric sheets **18***a* through **18***d* and the ground conductors **22** and **24** around the via-hole conductors B**1** through B**8** and B**11** through B**18**. Consequently, breakage around the via-hole conductors B**1** through B**8** and B**11** through B**18** is significantly reduced or prevented. Specifically, disconnections of the via-hole conductors B**1** through B**8** and B**11** through B**18** from the connection conductors **25***a* through **27***a*, **25***b* through **27***b*, **45***a* through **47***a* and **45***b* through **47***b* are reduced or prevented. Accordingly, the insertion loss of the high-frequency signal transmission line **10** is significantly reduced.

In the high-frequency signal transmission line **10**, also, undesired radiation is reduced or prevented. Specifically, in the signal line disclosed in WO 2011/007660, at a side of the signal line, sets of via-hole conductors are provided such that each set of via-hole conductors are connected to define a straight line. Therefore, undesired radiation is likely to occur through the intervals between the sets of via-hole conductors.

In the high-frequency signal transmission line **10**, on the other hand, the connection portions C**1** through C**4** are zigzag shaped when viewed from the y-direction. Accordingly, the width (size in the x-direction) of each of the connection portions C**1** through C**4** is greater than the width (size in the x-direction) of each set of via-hole conductors in the signal line disclosed in WO 2011/007660. Therefore, noise radiated from the signal line **20** is likely to be absorbed by the connection portions C**1** through C**4**. Thus, in the high-frequency signal transmission line **10**, undesired radiation from the negative and positive sides in the y-direction is reduced or prevented.

In the high-frequency signal transmission line **10**, the connection portions C**1** through C**4** are connected to the ground conductor **24** by contacting with the bridges **60** between the openings **30**. Thus, the potentials of the bridges **60** come close to the ground potential, and occurrences of undesired inductor components at the bridges **60** are significantly reduced or prevented.

In the high-frequency signal transmission line **10**, the characteristic impedance of the signal line **20** in the areas A**1** is greater than the characteristic impedance of the signal line **20** in the areas A**3** and A**4**. The characteristic impedance of the signal line **20** in the areas A**3** and A**4** are greater than the characteristic impedance of the signal line **20** in the areas A**2**. More specifically, between two adjacent bridges **60**, with increasing distance from one of the bridges **60** and with decreasing distance from the other of the bridges **60**, the impedance of the signal line **20** increases from a minimum value Z**2** to an intermediate value Z**3** and further to a maximum value Z**1** and thereafter decreases from the maximum value Z**1** to the intermediate value Z**3** and further to the minimum value Z**2**.

The width (size in the y-direction) W1 of the opening portions **30***b* is greater than the width (size in the y-direction) W2 of the opening portions **30***a* and **30***c*. Accordingly, the distance between the signal line **20** and the ground conductor **24** in the areas A**1** is greater than the distance between the signal line **20** and the ground conductor **24** in the areas A**3** and A**4**. Therefore, the magnetic field strength acting on the signal line **20** in the areas A**1** is greater than the magnetic field strength acting on the signal line **20** in the areas A**3** and A**4**. Thus, the inductance components of the signal line **20** in the areas A**1** are great. In other words, in the areas A**1**, the inductance of the signal line **20** is dominant.

On the other hand, the distance between the signal line **20** and the ground conductor **24** in the areas A**2** is smaller than the distance between the signal line **20** and the ground conductor **24** in the areas A**3** and A**4**. Therefore, the capacitance occurring on the signal line **20** in the areas A**2** is greater than the capacitance occurring on the signal line **20** in the areas A**3** and A**4**. Also, the magnetic field strength in the areas A**2** is smaller than the magnetic field strength in the areas A**3** and A**4**. Thus, in the areas A**2**, the capacitance on the signal line **20** is dominant.

As described above, in the areas A**1**, since almost no capacitance is generated between the signal line **20** and the ground conductor **24**, the maximum impedance value Z**1** results mainly from the inductance of the signal line **20**. In the areas A**2**, since great capacitance is generated between the signal line **20** and the ground conductor **24**, the minimum impedance value Z**2** results mainly from the capacitance. In the areas A**3** and A**4**, the intermediate impedance value Z**3** results from the inductance and the capacitance. Accordingly, the characteristic impedance of the signal line **20** changes cyclically so as to decrease from the maximum value Z**1** to the intermediate value Z**3** and to the minimum value Z**2** and thereafter increase from the minimum value Z**2** to the intermediate value Z**3** and to the maximum value Z**1**. The maximum impedance value Z**1** preferably is, for example, about 70Ω. The minimum impedance value Z**2** preferably is, for example, about 30Ω. The intermediate impedance value Z**3** preferably is, for example, about 50Ω. The maximum value Z**1**, the minimum value Z**2** and the intermediate value Z**3** are designed such that the characteristic impedance of the signal line **20** as a whole becomes a predetermined value (for example, about 50Ω).

The high-frequency signal transmission line **10**, further, achieves a reduction in the transmission loss by stabilization of the ground potential and an improvement in the shield characteristic. Specifically, in the high-frequency signal transmission line **10**, the width (size in the y-direction) W1 of the opening portions **30***b* is greater than the width (size in the y-direction) W2 of the opening portions **30***a* and **30***c*. Accordingly, in the high-frequency signal transmission line **10**, the magnetic energy of the signal line **20** in the areas A**1** is higher than the magnetic energy of the signal line in the areas A**3** and A**4**, and the magnetic energy of the signal line **20** in the areas A**2** is lower than the magnetic energy of the signal line in the areas A**3** and A**4**. Therefore, the characteristic impedance of the signal line **20** changes cyclically from Z**2**, Z**3**, Z**1**, Z**3**, Z**2** . . . in this order. Thus, the change of the magnetic energy along the signal line **20** from an area to its adjacent area in the x-direction is mild. Hence, at the borders between the openings **30** and the bridges **60**, the magnetic energy is small, and changes in the ground potential of the ground conductor **24** are reduced. Consequently, undesired radiation and transmission loss of a high-frequency signal are significantly reduced or prevented.

First Modification

A high-frequency signal transmission line **10***a* according to a first modification of a preferred embodiment of the present invention is described below with reference to the drawings. FIG. **7** is a sectional view of a connection portion C**1** of the high-frequency signal transmission line **10***a*.

The high-frequency signal transmission line **10***a* is different from the high-frequency signal transmission line **10** in the structure of the connection portion C**1**. Specifically, in the high-frequency signal transmission line **10***a*, the connection portion C**1** includes via-hole conductors B**1** through B**5** connected to one another. The via-hole conductors B**1** and B**5** that constitute respectively the both ends in the z-direction of the connection portion C**1** are located farther away from the center of bend than the via-hole conductor B**3** crossing the neutral surface S**0**. However, the via-hole conductors B**1** and B**5** are located nearer to the center of bend than the via-hole conductor B**4**. In the high-frequency signal transmission line **10***a*, the via-hole conductors B**1** and B**5** are not located at positions where great stresses act, and it becomes less likely that the via-hole conductors B**1** and B**5** hinder bending of the dielectric body **12**. Thus, in the high-frequency signal transmission line **10***a*, the dielectric body **12** is easy to bend.

Second Modification

A high-frequency signal transmission line **10***b* according to a second modification of a preferred embodiment of the present invention is described below with reference to the drawings. FIG. **8**A is an exploded view of a dielectric body **12** of the high-frequency signal transmission line **10***b*. FIG. **8**B is a sectional view of a connection portion C**1** of the high-frequency signal transmission line **10***b*. FIG. **8**C is a sectional view of dielectric sheets **18***a* through **18***e* before pressure bonding.

The high-frequency signal transmission line **10***b* is different from the high-frequency signal transmission line **10** in that the dielectric sheet **18***a* has openings Op**1**, Op**3**, Op**5** and Op**7** and in that the dielectric sheet **18***e* has openings Op**2**, Op**4**, Op**6** and Op**8**.

Specifically, as seen in FIGS. **8**A and **8**B, the opening Op**1** is located in the dielectric sheet **18***a* farther in the positive z-direction than the via-hole conductor B**2**, at a position to overlap with the via-hole conductor B**2** when viewed from the z-direction, and the opening Op**2** is located in the dielectric sheet **18***e* farther in the negative z-direction than the via-hole conductor B**3**, at a position to overlap with the via-hole conductor B**3** when viewed from the z-direction. Similarly, the opening Op**3** is located in the dielectric sheet **18***a* farther in the positive z-direction than the via-hole conductor B**2**, at a position to overlap with the via-hole conductor B**6** when viewed from the z-direction, and the opening Op**4** is located in the dielectric sheet **18***e* farther in the negative z-direction than the via-hole conductor B**3**, at a position to overlap with the via-hole conductor B**7** when viewed from the z-direction.

Also, as seen in FIG. **8**A, the opening Op**5** is located in the dielectric sheet **18***a* farther in the positive z-direction than the via-hole conductor B**12**, at a position to overlap with the via-hole conductor B**12** when viewed from the z-direction, and the opening Op**6** is located in the dielectric sheet **18***e* farther in the negative z-direction than the via-hole conductor B**13**, at a position to overlap with the via-hole conductor B**13** when viewed from the z-direction. Similarly, the opening Op**7** is located in the dielectric sheet **18***a* farther in the positive z-direction than the via-hole conductor B**12**, at a position to overlap with the via-hole conductor B**16** when viewed from the z-direction, and the opening Op**8** is located in the dielectric sheet **18***e* farther in the negative z-direction than the via-hole conductor B**13**, at a position to overlap with the via-hole conductor B**17** when viewed from the z-direction.

In the high-frequency signal transmission line **10***b*, as illustrated in FIG. **8**C, after making the openings Op**1** through Op**8**, the dielectric sheets **18***a* through **18***e* are stacked and pressure-bonded together. Further, in forming the protective layer **14**, openings Op**9** through Op**12** are made in the protective layer **14** such that the openings Op**1**, Op**3**, Op**5** and Op**7** are not covered by the protective layer **14**.

In the high-frequency signal transmission line **10***b* having the structure above, the openings Op**1** through Op**8** are provided, and thus, the dielectric sheets are removed from the portions around the connection portion C**1** where great stresses act. This makes it easier to bend the dielectric body **12**. The openings Op**1** through Op**8** may be made in only one of the dielectric sheets **18***a* and **18***e*. Further, the ground conductors **22** and **24** may include openings (non-conductive portions) at positions that overlap with the openings Op**1** through Op**8**.

Third Modification

A circuit board **10***c* according to a third modification of a preferred embodiment of the present invention is described below with reference to the drawings. FIG. **9** is a perspective view of the circuit board **10***c*.

The circuit board **10***c* is, for example, a thin flexible circuit board provided in an electronic device as a subsidiary circuit board separate from a main circuit board. The circuit board **10***c* includes a high-frequency signal transmission line having the same structure as the dielectric body **12** of the high-frequency signal transmission line **10** in a stacked body of dielectric layers. (In FIG. **9**, only the signal line **20** is indicated, and the ground conductors **22** and **24**, and the connection portions C**1** through C**4** are not indicated.) On the circuit board **10**, components **62** are mounted as needed. While the high-frequency signal transmission line **10** is strip-shaped, the circuit board **10***c* is rectangular or substantially rectangular. The circuit board **10***c* including the high-frequency signal transmission line that is bent when used may include the connection portions C**1** through C**4**.

Other Preferred Embodiments

High-frequency signal transmission lines according to the present invention are not limited to the high-frequency signal transmission lines **10**, **10***a* and **10***b*, and the circuit board **10***c* according to the preferred embodiments above, and various changes are possible within the scope of the present invention.

In the high-frequency signal transmission line **10**, the via-hole conductor B**1** may cross the neutral surface S**0**. In this case also, in the connection portion C**1**, the via-hole conductors B**1** and B**4** preferably are located farther away from the center of bend than the via-hole conductors B**2** and B**3**. With this arrangement, the via-hole conductors B**1** and B**4** are not located at positions where great stresses act, and it becomes less likely that the via-hole conductors B**1** and B**4** hinder bending of the dielectric body **12**.

The connection portions C**1** through C**4** may be located outside the section D.

If there are two or more bending sections D in the dielectric body **12**, the via-hole conductors located at the both ends in the z-direction of a connection portion shall be located farther away from the center of bend of the nearest section D from the connection portion than the other via-hole conductors of the connection portion. Also, the via-hole conductors located at the both ends in the z-direction of the connection portion shall be located farther away from the center of bend of the nearest section D from the connection portion than the via-hole conductor of the connection portion crossing the neutral surface S**0**.

In the high-frequency signal transmission line **10**, the central axis of the via-hole conductor B**1** and the central axis of the via-hole conductor B**4** are at slightly different positions in the x-direction, but the central axes of the via-hole conductors B**1** and B**4** may be at the same position in the x-direction. Similarly, the central axis of the via-hole conductor B**1** and the central axis of the via-hole conductor B**4** are at slightly different positions in the y-direction, but the central axes of the via-hole conductors B**1** and B**4** may be at the same position in the y-direction.

In the high-frequency signal transmission line **10**, the ground conductor **24** (second ground conductor) includes openings **30**. However, the openings **30** do not always need to be provided, and the ground conductor **24** may be formed as a continuous conductor.

In contrast, the ground conductor **22** as well as the ground conductor **24** may include openings.

In the high-frequency signal transmission line **10**, the via-hole conductors B**1** and B**4** are located at different positions from the via-hole conductors B**2** and B**3** so as not to overlap with the via-hole conductors B**2** and B**3** at all when viewed from the z-direction. However, the via-hole conductors B**1** and B**4** may overlap with the via-hole conductors B**2** and B**3** when viewed from the z-direction. In order to facilitate bending of the dielectric body **12** and to diminish or eliminate the risk of breakage around the via-hole conductors, however, it is more desired that the via-hole conductors B**1** and B**4** do not overlap with the via-hole conductors B**2** and B**3** at all when viewed from the z-direction.

As thus far described, preferred embodiments of the present invention are useful in a high-frequency signal transmission line and an electronic device, and preferred embodiments of the present invention provide the advantage of facilitating bending.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

1. A high-frequency signal transmission line that is bent when used, the high-frequency signal transmission line comprising:

a body including dielectric layers stacked on top of one another;

a signal line provided in the body;

a first ground conductor located at one side in a stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers;

a second ground conductor located at another side in the stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; and

a connection portion including a plurality of interlayer connection conductors, each of the interlayer connection conductors pierced in one of the dielectric layers, and a plurality of connection conductors, each of the connection conductors provided on one of the dielectric layers, the connection portion configured to connect the first ground conductor to the second ground conductor; wherein

two of the interlayer connection conductors that constitute both ends in the stacking direction of the connection portion are located farther away from a center of a bending section where the body is to be bent than the other interlayer connection conductors of the connection portion; and

openings are located respectively in ones of the dielectric layers located at the one side and the another side in the stacking direction in relation to the other interlayer connection conductors, at positions that overlap with the other interlayer connection conductors.

2. The high-frequency signal transmission line according to claim **1**, wherein the connection portion is located within the bending section where the body is to be bent.

3. The high-frequency signal transmission line according to claim **1**, wherein

the second ground conductor includes a plurality of openings arranged along the signal line; and

the connection portion is connected to the second ground conductor by contacting with a portion between adjacent ones of the openings.

4. A high-frequency signal transmission line that is bent when used, the high-frequency signal transmission line comprising:

a body including dielectric layers stacked on top of one another;

a signal line provided in the body;

a first ground conductor located at a side in a stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers;

a second ground conductor located at another side in the stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; and

a connection portion including a plurality of interlayer connection conductors, each of the interlayer connection conductors pierced in one of the dielectric layers, and a plurality of connection conductors, each of the connection conductors provided on one of the dielectric layers, the connection portion configured to connect the first ground conductor to the second ground conductor; wherein

two of the interlayer connection conductors that constitute both ends in the stacking direction of the connection portion are located farther away from a center of a bending section where the body is to be bent than another of the interlayer connection conductors of the connection portion crossing a neutral surface of the bending section.

5. The high-frequency signal transmission line according to claim **4**, wherein openings are located respectively in ones of the dielectric layers located at the one side and the another side in the stacking direction in relation to the another of the interlayer connection conductors crossing the neutral surface, at positions that overlap with the another of the interlayer connection conductors crossing the neutral surface.

6. The high-frequency signal transmission line according to claim **4**, wherein the connection portion is located within the bending section where the body is to be bent.

7. The high-frequency signal transmission line according to claim **4**, wherein

the second ground conductor includes a plurality of openings arranged along the signal line; and

the connection portion is connected to the second ground conductor by contacting with an area between adjacent ones of the openings.

8. An electronic device comprising:

an article; and

a high-frequency signal transmission line that is bent when used; wherein

the high-frequency signal transmission line includes:

a body including dielectric layers stacked on top of one another;

a signal line provided in the body;

a first ground conductor located at one side in a stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers;

a second ground conductor located at another side in the stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; and

a connection portion including a plurality of interlayer connection conductors, each of the interlayer connection conductors pierced in one of the dielectric layers, and a plurality of connection conductors, each of the connection conductors provided on one of the dielectric layers, the connection portion configured to connect the first ground conductor to the second ground conductor; wherein

two of the interlayer connection conductors that constitute both ends in the stacking direction of the connection portion are located farther away from a center of a bending section where the body is to be bent than another of the interlayer connection conductors of the connection portion crossing a neutral surface of the bending section; and

a main surface of the body nearer to the first ground conductor in relation to the signal line contacts the article.

9. The electronic device according to claim **8**, wherein the second ground conductor includes a plurality of openings arranged along the signal line.

10. The electronic device according to claim **9**, further comprising a case housing the article and the high-frequency signal transmission line; wherein

a main surface of the body nearer to the second ground conductor in relation to the signal line faces an inner surface of the case with a predetermined space.

11. The electronic device according to claim **8**, wherein openings are located respectively in ones of the dielectric layers located at the one side and the another side in the stacking direction in relation to the another of the interlayer connection conductors crossing the neutral surface, at positions that overlap with the another of the interlayer connection conductors crossing the neutral surface.

12. The electronic device according to claim **8**, wherein the connection portion is located within the bending section where the body is to be bent.

13. The electronic device according to claim **8**, wherein

the second ground conductor includes a plurality of openings arranged along the signal line; and

the connection portion is connected to the second ground conductor by contacting with an area between adjacent ones of the openings.

14. An electronic device comprising:

an article; and

a high-frequency signal transmission line that is bent when used; wherein

the high-frequency signal transmission line includes:

a body including dielectric layers stacked on top of one another;

a signal line provided in the body;

a first ground conductor located at one side in a stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers;

a second ground conductor located at another side in the stacking direction in relation to the signal line so as to face the signal line across one or more of the dielectric layers; and

a connection portion including a plurality of interlayer connection conductors, each of the interlayer connection conductors pierced in one of the dielectric layers, and a plurality of connection conductors, each of the connection conductors provided on one of the dielectric layers, the connection portion configured to connect the first ground conductor to the second ground conductor; wherein

two of the interlayer connection conductors that constitute both ends in the stacking direction of the connection portion are located farther away from a center of a bending section where the body is to be bent than another of the interlayer connection conductors of the connection portion crossing a neutral surface of the bending section;

openings are located respectively in ones of the dielectric layers located at the one side and the another side in the stacking direction in relation to the other interlayer connection conductors, at positions that overlap with the other interlayer connection conductors; and

a main surface of the body nearer to the first ground conductor in relation to the signal line contacts the article.

15. The electronic device according to claim **14**, wherein the second ground conductor includes a plurality of openings arranged along the signal line.

16. The electronic device according to claim **15**, further comprising a case housing the article and the high-frequency signal transmission line; wherein

a main surface of the body nearer to the second ground conductor in relation to the signal line faces an inner surface of the case with a predetermined space.

17. The electronic device according to claim **14**, wherein the connection portion is located within the bending section where the body is to be bent.

18. The electronic device according to claim **14**, wherein

the second ground conductor includes a plurality of openings arranged along the signal line; and

the connection portion is connected to the second ground conductor by contacting with a portion between adjacent ones of the openings.

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